Practical Methods of GIS for Archaeologists: Spatial Division in a Large Area

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Abstract

The use of GIS software is ideal for the investigation of archaeological problems which involve the geographical distributions of sites. Its ability to combine qualitative and quantitative data and also to allow for effective categorization, multi-layering and distance-measurement renders it an indispensable tool for the investigation of archaeological issues concerning distribution patterns.

The present work demonstrates the importance of Geographical Information Systems (GIS) in archaeology and more specifically, an attempt is made to resolve the problem of division of a large geographical area in smaller areas with specific rational and realistic criteria, using Mycenaean Messenia as a case study. Messenia is considered one of the most important Mycenaean regions of Greece due to the great number and significance of Mycenaean sites hosted therein.

Due to the large size of the study area (2.991 Square Kilometers), it was preferable to divide the total of the area into smaller sub-areas, due to the following reasons: The smaller areas are more efficient for analyzing, in terms of field research as well as in office preparation work. More generally, as far as field research is concerned, the smaller the area, the more thorough and in greater detail is the geomorphologic information to be studied. Regarding office work, the depictions (always depending upon the scale), will have and present a greater detail.

Keywords - *GIS, Spatial Division, Spatial Analysis, Archaeology, Path Distance.*

I. INTRODUCTION

The study area is the Prefecture of Messenia (Figure 1); at the SW of Peloponnese, Greece. The area measures 2991 square kilometers and has been continuously inhabited since prehistory1. During the Mycenaean era (1600 -1100 BC), it stood out as the Kingdom of Pylos, one of the most important centers of the Mycenaean world2. As a matter of fact, new archaeological evidence (findings, locations and burial complexes) are unearthed every year throughout the region, hence the selection of the study area in the following example3.

Figure 1: Study area – The Prefecture of Messenia located at the SW of Greece.

II. METHODOLOGY AND RESULTS

Factor 1: HydroZones (Frz)

Due to the extension of the area it was decided to proceed to a division into smaller areas to assist the needs of the analysis. After the archaeological locations where imported into the map as shapefiles in a GIS environment, and upon observation that most of them are located very closes to the hydrographic network, it was decided to divide the area according to the natural geographic boundaries such as the rivers and the large streams of the area.

It should be noted that, the present division of land into administrative boundaries and borders is a more contemporary way of dividing land. However, the ancient man divided land taking into consideration the extant and easily distinguishable elements of the natural environment such as rivers, mountains, cliffs etc, to determine his own space. This methodological approach has not changed greatly throughout the centuries as even today the great natural boundaries are often used as administrative boundaries separating prefectures, regions and countries. Rivers, streams and mountain ranges are landmarks for humans and are used to create borders and define the land and its sub areas.

Taking this under consideration, the author suggests that the first and most important division of the land for any given study area, to be performed based upon the location of grand rivers and mountain ranges.

The methodology followed is also simpler as the digitization of physical boundaries, can be performed using either maps or satellite images[4]. Then, polygons are created on the limits of the digitized data, first between the first two rivers found and then by continuing to set boundaries of areas, until the total of the study area is digitized. With this method, the first division of the study area is realized and the first factor (Frz) of area division will be created (Figure 2).

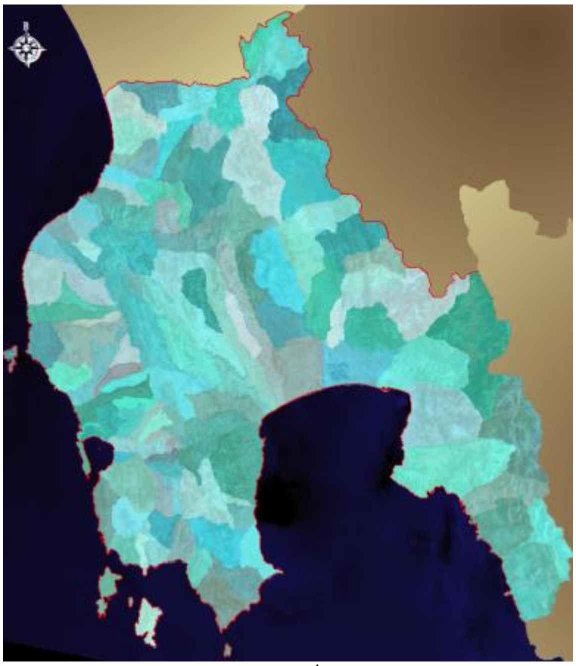


Figure 2: Creation of the 1st Division Factor (Frz)

B. Factor 2: Time in Minutes (Ftm)

In the case that the landmarks are too far away from one another, or in the case that for any reasons the divided area is to be redivided into smaller areas, other dividing factors are to be incorporated. Path Distance is the second and very important factor. This defines the distance covered by an average person walking from one area to another, taking into consideration the slopes of the terrain, natural limits and other difficulties that maybe encountered while walking. Therefore, the Path Distance factor is used to correlate the accessibility through the topographical relief and provides some indications of movement cost, in terms of time, through a multi - morphological landscape. In GIS this methodology is referred to, as Cost Surface Analysis [5],[6].

The concept of space topography in relation to the ease of accessibility and mobility of its inhabitants is a consistent methodological approach to habitation. The spatial component of a site is an important element, given the ability to locate a site and may have played an important role in society. It should also be noted that accessibility and visibility can be considered as important elements in the process of socialization and the interpretation given by people to the habitat of their choice.

The factor determining the cost of energy that the population will have to pay to exploit an area is distance, as human populations tend to exploit areas rich in resources located some distance away from their habitat. Thus, it is estimated that there is a certain limit, beyond which the exploitation of the resource becomes unprofitable, since the cost outweighs the benefits that the latter entails. The definition of this limit varies, as various factors such as technology, population pressure, the economic system of the community, etc. are involved in its formation. Soil quality, geology and hydrology and then the character of the society in the Mycenaean era determines the habitat and the decisions related to dwelling and land exploitation. Ethnographic studies indicated that these limits differ, for example, from nomad populations to farmers, since a stock-breeding society may have an increased holding area of up to two hours walking radius due to the rearing of the animals.

C. Modeling Time

Travelling models methodologically have to tackle a series of problems based on the time travel that they realize, as well as on other factors. However, it is generally accepted that the hypothetical motion motives could define the spatial correlation among the dwellings, the Mycenaean sites and the points of interest within the study area.

The travelling model used in this study was based on Tobler's algorithm[7] and is bibliographically referred to as Tobler's Hiking Function (Equation 1). It is an anisotropic algorithm that calculates the speed of movement as a function of the slope of the terrain. It was created by geographer Waldo Tobler based on empirical data published by Imholf[8], concerning hiking performed by soldiers in areas with different terrain heterogeneity. This function calculates the speed of motion as a function of the slope surface in degrees.

$$W = 6e^{-3.5\,|\,s\,+\,0.05\,|}$$

Syntax in Excel W=6*EXP(-3.5*ABS(TAN(RADIANS(x))+0,05))

Equation 1: Tobler's Algorithm

where:

W – The speed of motion (km / h)

s - The slopes of the terrain (degrees)

e - The basis of the natural logarithm (about 2.718).

The formula claims a top speed of just under 6 km / h, which is achieved when the model-factor walks slightly downhill. This formula, and the methodologies based on it, have been analyzed and discussed in a series of archaeological motion analyses such as those by van Leusen[9] and Kondo & Seino[10].

The choice of application of this algorithm, in this study, was made because it allows the calculation of the time required to cover a distance on a heterogeneous terrain, as is the terrain in the study area presented in this paper. In addition, this algorithm has been successfully tested with both archaeological and ethnographic data[11].

D. Creating the Travelling Model Cost Zones

The journey duration for each site in the study area, was calculated as cumulative cost area, using Possible Centers as departure points. The costing surfaces is created through this methodology, were anisotropic, meaning that the analyses took into account the directionality of the model movement (whether walking downhill, uphill or parallel to the slope of the ground). This is a particularly important element in the discussion of motion and travel distance as a result of the speed of human movement, since velocity should not be considered to be the same when walking in angled areas (eg it is assumed that speed motion is not the same i.e. when climbing 30° tilt and when descending 30° downhill).

The ARC - MAP 10.1 software was used to create the Travelling Model. The data - levels used for this study are as follows:

1. Digital Elevation Model (DEM):

A high-resolution Raster file was used for the proper operation of the model. The smaller the analysis sought through the model, the higher should the resolution be in the DEM employed The larger the DEM pixel size, the less realistic the relief becomes[12]. For example, in an 80m DEM, only one contour value is used for a 1,600m area. In addition, the integration and categorization of the slope in a Travelling Model is not as important in a large cell-size Raster file, because the values of the cells will be very close to one another. A model lacking mountains or other features will be almost round. This means that such a model could be equally well be created, by a model of only circular bands, based on Euclidean distance.

2. Conversion of Digital Terrain Model to Ground Gradients:

From the DEM file, the slope file is extracted. It is noticed that the values of the extracted file, cannot be used to calculate the directions. In addition, the file does not include negative values for moving to downhill gradients. This problems can however be automatically corrected in the following stages of processing.

3. Conversion of the slope file into a time-traveller raster image file

The file classes were reclassified in order to convert the slope values into time (seconds) / cell (pixel) values that are traversed. Here the Tobler algorithm is used; this is essentially a continuous curve, and can therefore be used as a formula to generate any desired value, in km / h of walking speed and for any slope in degrees (x). The process may also be used to get the negative values of the model and render it as realistic as possible.

After the final data processing the result is multiplied by 200 to receive an integer number. Due to the average value there is a small deviation of speed for slopes between -5 and +5 degrees. Slopes over 35% could be considered as obstacles and therefore a much higher value of cost is attributed.

4. Final result of the Cost Surface Analysis

The final step for the calculation of the Travelling Model is to insert the point files of the dwellings in a GIS environment, and combined them to the final raster file in which the movement cost (expressed in minutes) has been calculated in each cell.

In the ArcGis software, the cost distance tool, divides the value of cells per cell size. However, in this paper a specific time unit (minutes) is used. Therefore, the values that automatically created by the final raster file have to be simplified.

The resulting Travelling model contains information on the movement expressed in minutes for the whole study area. Physical barriers such as rivers have not be used on purpose, as it has been considered that there should have been ways of transport (ie bridges) and was therefore thought that the model would be more realistic (Figure 3).

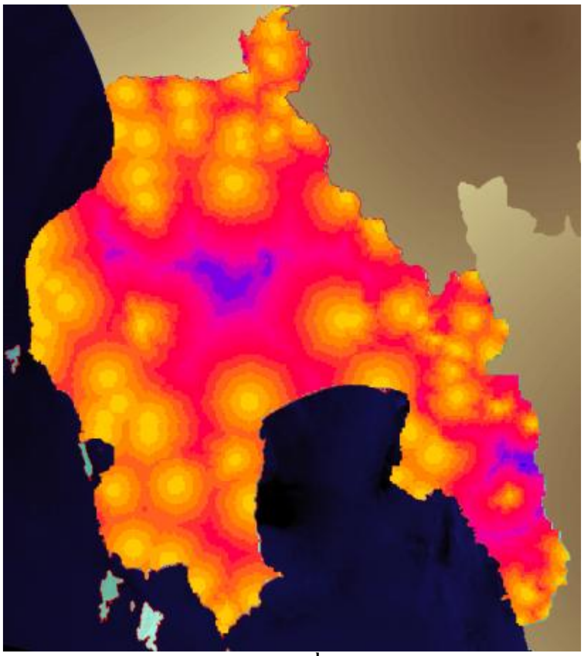


Figure 3: Creation of the 2nd Division Factor (Ftm)

E. Factor 3: Site Zones (Fsz)

The third factor to be considered is surely the points of interest. The more the sites and points of interest gathered in an area, the stronger the indication of habitation. An easy methodological approach for the creation of this factor is the chromatic gradation of the units created by the natural boundaries factor. As an alternative, the Kernel's method of the site density calculation can be employed.

At this point, it should be stressed that GIS is just a tool and it's up to the user to decide how they are to be used. Various methods can be used to provide various solutions and visualize various results. What is necessary is to know why each action is performed and where the researches wishes to end following each method available. It is up to the user to choose the appropriate method, tools and steps to reach the desired results.

1. Chromatic Gradation Method

The methodological approach of the chromatic gradation uses the previously created layer of the first division of the study area (Frz Factor), such as in the case presented in this paper (Figure 4). The limits of the divided areas are visualized in polygonal data and are combined to the points of interest (point data shapefiles). Using various chromatic gradations each polygon is defined according to the number of the points of interest it contains. A usual proposal for chromatic gradation employs red color for areas of very high concentration, orange for areas of high concentration, yellow for medium and green for areas with no points of interest. The number of colors employed is up to the choice of the user: depending on the detail of the final visualized product the user may employ more or less colored bands for more or less categorization and detail respectively.

The benefits of this approach include ease of use even for a beginner GIS user [13], easy to read information for both the user and the receiver of the final product and inclusion of several layers within the same map.

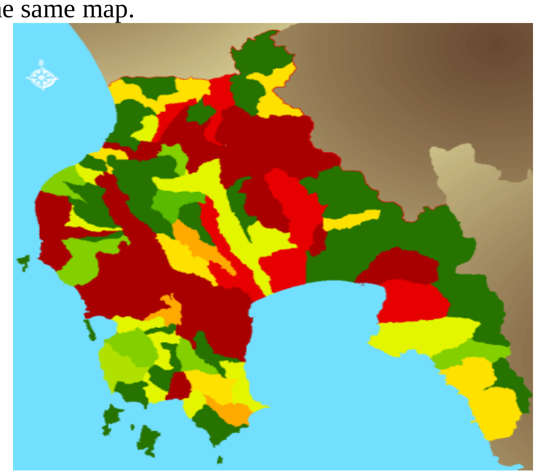


Figure 4: Creation of the 3rd Division Factor (Fsz) using Chromatic Gradation Method

2. Kernel's site density calculation

Kernel's site density calculation is a known parametric technique in which a two dimensional surface of density (kernel) is created around its observation point, in order to create a more gradual estimation of the distribution from the center of area of study, extending outwards. The two parameters that can be used are the shape of the nucleus and the radius of the table.

Applications in archaeology have been presented by Beardah & Baxter [14] and Beardah[15]. In general, the use of a very large radius related to a more gradual distribution, whereas the very small radius will create peaks around the studied points of interest which may not be equivalent to the actual distribution.

Kernel's site density calculation was realized with the density tool of the ArcGis 10.1 Spatial Analyst. The radius around each pixel was defined at 2500 meters. The software automatically seeks for further points in order to create a density map (Figure 5).

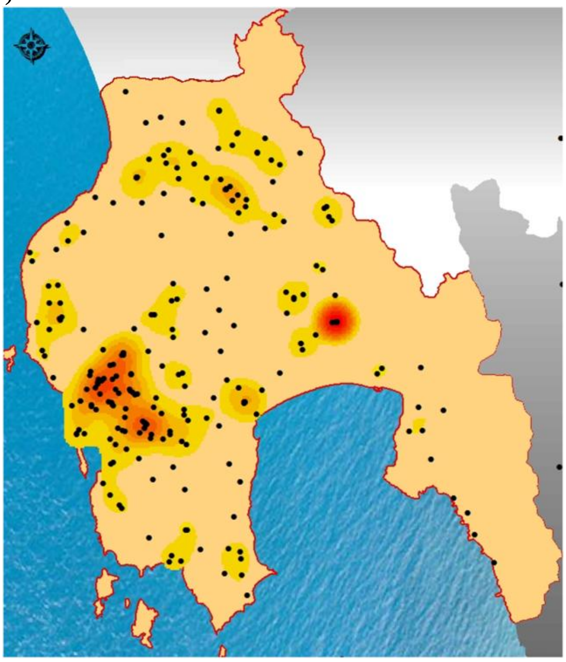
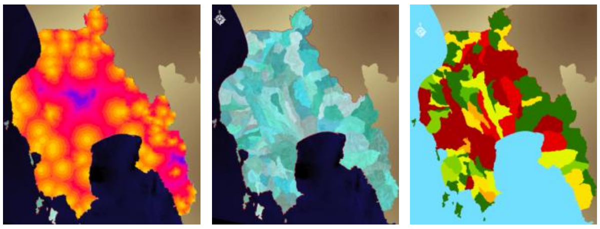


Figure 5: Creation of the 3rd Division Factor (Fsz) using Kernel's site density calculation Method

F. Final Result of Spatial Division Map

Based upon the above and having set an one hour time limit (Ftm) around a dwelling, and having combined the natural boundaries of rivers and streams (Frz), as well as the sites zones factor (Fsz) the following map was created. The three factors, therefore, were combined for the final result as we can see in Figure 6.

(a) Factor Time In Minutes (Ftm) + (b) Factor Hydro Zones (Frz) + (c) Factor Sites Zones (Fsz)



(a) + (b) + (c)

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Final Result of Spatial Division for Prefecture of Messenia

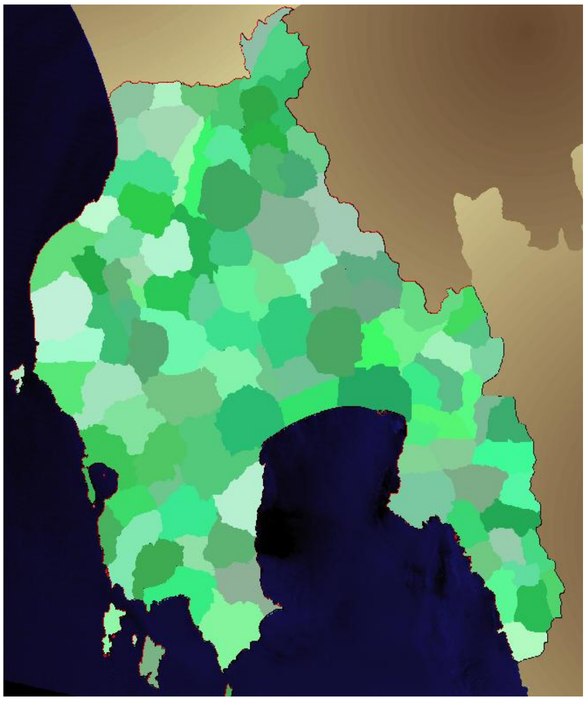

Figure 6: The Final Result of the Spatial Division (with different colors for every new seperated territory)

III. CONCLUSIONS

In brief, in order to achieve a realistic land separation, aiming to the greater simulation of land division into zones that could have possibly been the actual areas in which the Mycenaean habitants may have lived, worked and wandered around, three factors of equal weight criteria are used.

The first one is the Factor of Physical Boundaries, and it is symbolized as Frz (Factor Hydro Zones). The second one is the Time Factor, symbolized as Ftm^{60}(1) and the third one is the Sites Zones factor, symbolized as Fsz.

This proposal could be used to divide a large area into smaller ones. It is expected that such a land division could lead to more accurate results and understanding of any prehistoric or archaeological or more recent population, when combined to archaeological findings, spatial statistics and spatial analysis in general and shed more light towards the understanding of space occupation and habits of the civilization studied.

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(1) The ^{60} superscript expresses the walking time defined around each area of study and it is written in the acronym so that the user may easily understand the time limit set. In the case presented in this paper, one hour (60 minutes) of walking was set around the divided areas. Depending on the needs of the user, one may set shorter time and create more distance zones. It is essential for each researcher, to have a basic knowledge of the area of study and the daily activities of its inhabitants in order to define the appropriate for each case walking time. For example, modern people are much slower in walking compared to prehistoric populations who moved a lot.

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