ARCHAEOLOGICAL AND NON-ARCHAEOLOGICAL EXCAVATIONS OF MODERN CITIES: A CONTRIBUTION TO WHERE TO DEVELOP AND WHERE TO CONSERVE

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ABSTRACT

It is a typical Mediterranean phenomenon that modern cities are built on top of ancient cities. Snapshots of this palimpsest are viewed sometimes during the implementation of construction projects, primarily building permits, which involve soil removal and extensive digging. The present application focuses on Patras, Greece and makes use of a set of dig reports dating between 2004 and 2008, in which the absence or presence of archaeological deposits is reported. It is considered whether archaeological and non-archaeological excavations can provide a quick and functional way to record the archaeological palimpsest buried underneath modern cities and for this reason Voronoi tessellation, conventional statistics and spatial analysis are applied. Their predictive strength is tested and a digital map of the potentially archaeological territory in Patras is produced. The results are then compared with the known archaeological profile of the city and their implications for cultural heritage management and urban planning are discussed.

INTRODUCTION

It is a typical Mediterranean phenomenon that modern cities are built on top of ancient cities [1]. In every such case conserved archaeological monuments and sites bear evidence of a wealthy deposit lying underneath and creating the city’s palimpsest. Snapshots of this palimpsest are viewed sometimes during the implementation of construction projects, primarily building permits, which involve soil removal and extensive digging.

According to the Greek Legislation (Law 3028/28-6-2002, Presidential Decree 8/7/1993) construction works or any other action that involves ground disturbance must be inspected by a member of the Archaeological Service. If archaeological remains come to light during soil removal, the works stop temporarily until a salvage archaeological excavation is carried out. When the excavation finishes the Local Board of Monuments makes a decision regarding the treatment of the immovable architectural features (in situ conservation, reburial, exposure, deconstruction etc.) and may demand modification of the original construction plan in order to protect the archaeological remains and allow the construction works to continue. Due to the overall delay incurred, landowners sometimes choose to cover part or the whole of the excavation costs, although it is not compulsory, in anticipation of avoiding much unwanted delay.

As the majority of ground disturbance activities in Greek cities occur on small private house plots and to a lesser extent on the road network, it is obvious that both the delay of the construction works as well as the cost of archaeological operations represent a heavy burden for landowners and citizens. On the other hand, there is no evidence that the interested parties are actually informed or alerted to the possibility of discovering archaeological remains on their site prior to
investment.

As a result, developers lose money and time, because of unexpected delay and unwanted modification of plans, while the archaeologists do not have the chance to conduct a proper research. Though artifacts are recovered and immovable structures are recorded, this type of archaeological research is characterized by pressure of time, lack of available resources and the inevitable tension between archaeologists and the developers or land proprietors [2, p.495]. Had both sides been informed and alerted to the possibility of discovering antiquities on a certain dig site in advance, better decisions might have been reached regarding both the location and extent of the construction works and the type of required archaeological management. However, this would call for a different approach in urban planning according to which heritage management would be integrated into current and future urban development. This paper puts forward a method for understanding and estimating the archaeological potential of every new dig in a city based on reports of past digs and is followed by a discussion as to how the results correspond to the known archaeological pattern of the city. The rationale behind the application is that these entities nearer to an entity with a known characteristic (in our case presence/absence of archaeology) are more likely to demonstrate a related characteristic than those further away, which is referred to as the “First Law of Geography “[3].

![Figure 1: The distribution of digs of years 2004-8 within the City Plan of Patras](image)

**THE DATABASE OF PATRAS ARCHAEOLOGICAL DIGS**

The case study is Patras, a city of approx. 200,000 inhabitants in southern Greece. By using the term “archaeological digs” I refer to those sites where soil removal processes produced archaeological remains. Archaeological digs are recorded anyway, because excavation follows. Nevertheless, the information of absence of archaeology is equally useful, because it allows the documentation of the boundaries of ancient settlement phases and enables us to determine the potential of any dig for not containing archaeological resources as well. These are the “non-archaeological digs”, in which construction activities proceed uninterrupted. The implications of both types for urban planning and cultural management have never been adequately sought,
despite that there have been periods of very extensive and intensive building activity in various Greek cities. Although this is not the case nowadays, due to the overall economic crisis, 500 digs and 52 excavations have taken place in the wider region of Patras only in 1995 [4, p.51]. However, it was only after 1999 that an atypical bureaucratic procedure took effect by the local archaeologists and guards of the region of Patras. Since then all digs that take place in Patras are being recorded in written reports.

Though the reports have had no other use so far than to confirm the guards’ attendance during the works, the potential for delving into spatial analysis of the information they carry is considered. By engaging a range of analytical tools, we may contribute to a more informed decision making on where to build and where to conserve, in an ever expanding urban environment.

The present application makes use only of the absence/presence of archaeology type of information, which is the commonest to be found in all dig reports. A set of reports dating between 2004 and 2008 were used. The database contained 941 records, each corresponding to a single dig either in a land plot, or in the road network. The database was connected to a map of the City Plan of Patras and 941 points were digitized, representing the digs (Figure 1).

VORONOI TESSELATION IN ARCHAEOLOGY

Voronoi tessellation is generated from a point distribution. Each point location of a dataset is enclosed by one discrete polygon. The same polygon contains also all the land that is closer to that point than any other. Distance can be calculated according to different metric spaces but usually in the Euclidean space. The boundary between two polygons falls at the midpoint of the distance between their defining points. In order to calculate the boundary arc of a certain polygon straight lines are drawn between the defining point and its neighboring ones. Then, by projecting perpendicular lines from the midpoints, the polygon is formed with peaks at the intersection of these lines [5, p.289, 6, p.150, 7, p.211, 8, p.106].

Voronoi tessellation or Thiessen polygons have been used in a number of different applications in the social and environmental sciences. They have been used in archaeology since the late 1960’s. Applications were intended to investigate territoriality with selected archaeological entities acting as the centroids of polygons. In this way all locations within each polygon belonged to the realm of each centroid, which was assumed to have exercised some kind of influence upon them. As a result Thiessen polygons were primarily used to study the sociopolitical environment of competition rather than environmentally determined catchments and to visualize levels of hierarchy [9, p.164, 10, p.351, 11, p.255, 12, p.223, 13, 14]. An exhaustive account can be found elsewhere [9, p.150, 7, p.212].

Decreasing use of tessellation currently is attributed to its serious methodological shortcomings [9, p.150-164, 13, p.146-151, 15, p.993, 6, p.151 & 183, 7, p.211-213]. One way to contemplate with some of them is to weight the polygons by attributing to the points some quantity that differentiates them to a certain criterion. Again, the acknowledged subjectivity in determining the values of the variable to be used accounts for limited use. Then why do I proceed with this methodology? A list of disadvantages and why they affect little my case study is provided below.
For these reasons Voronoi polygons were considered appropriate and were eventually applied. Their predictive strength was tested over a period of five years, by calculating the percentage of “right predictions” that occurred every year, namely archaeological digs in cumulative archaeological tessellation and non-archaeological digs in cumulative non-archaeological tessellation. In this way it was possible to test how indicative the tessellation map is of the potential of archaeological or not occurrence at any ground disturbance activity in the city.

**SPATIAL ANALYSIS**

The area under study comprises the “Official Building Regulations” of 2008 for Patras (Figure 1). The total area is 2,270 hectares in which 941 digs dating between 2004 and 2008 are located (Table 1).

<table>
<thead>
<tr>
<th>Table 1: Frequency table of the digs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Archaeological digs</td>
</tr>
<tr>
<td>Non-archaeological digs</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

By creating Voronoi polygons for each year’s digs we could compare the space allocated to archaeological or non-archaeological points of one year with the dug sites of the next year and examine to what extent the latter fall inside. Voronoi polygons were generated from points representing the digs of the case study. The point pattern for every year was used and points were converted to Voronoi polygons. The output coverage inherited that part of the point attribute table, which contained the information on the absence or presence of archaeological finds in each of the digs. The point distribution for each year’s digs was overlaid on the cumulative tessellation of the
previous years’ digs gradually (Table 2). Year 2004 is omitted in the table since this is the starting year of the project.

Table 2: Digs in cumulative Voronoi polygons of the previous years’ digs

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Archaeological digs in</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>archaeological polygons</td>
<td>7/24</td>
<td>15/68</td>
<td>9/15</td>
<td>13/19</td>
<td>44/126</td>
</tr>
<tr>
<td>(29.17%)</td>
<td>(22.06%)</td>
<td>(60%)</td>
<td>(68.42%)</td>
<td>(34.92%)</td>
<td></td>
</tr>
<tr>
<td><strong>Archaeological digs in</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-archaeological polygons</td>
<td>17/24</td>
<td>53/68</td>
<td>6/15</td>
<td>6/19</td>
<td>82/126</td>
</tr>
<tr>
<td>(70.83%)</td>
<td>(77.94%)</td>
<td>(40%)</td>
<td>(31.58%)</td>
<td>(65.08%)</td>
<td></td>
</tr>
<tr>
<td><strong>Non-archaeological</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>digs in non-archaeological polygons</td>
<td>149/165</td>
<td>289/302</td>
<td>88/101</td>
<td>81/87</td>
<td>607/655</td>
</tr>
<tr>
<td>(90.30%)</td>
<td>(95.70%)</td>
<td>(87.13%)</td>
<td>(93.10%)</td>
<td>(92.67%)</td>
<td></td>
</tr>
<tr>
<td><strong>Non-archaeological</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>digs in archaeological polygons</td>
<td>16/165</td>
<td>13/302</td>
<td>13/101</td>
<td>6/87</td>
<td>48/655</td>
</tr>
<tr>
<td>(9.70%)</td>
<td>(4.3%)</td>
<td>(12.87%)</td>
<td>(6.89%)</td>
<td>(7.33%)</td>
<td></td>
</tr>
<tr>
<td>“Right predictions”</td>
<td>156/189</td>
<td>304/370</td>
<td>97/116</td>
<td>94/106</td>
<td>651/781</td>
</tr>
<tr>
<td>(82.54%)</td>
<td>(82.16%)</td>
<td>(83.62%)</td>
<td>(88.68%)</td>
<td>(83.35%)</td>
<td></td>
</tr>
</tbody>
</table>

While the 2005 point distribution laid over the polygons produced for 2004 dig pattern (Figure 2, top left), the 2006 point distribution laid over the polygons of both 2004 and 2005 pattern (Figure 2, to right) and so on (Figures 2, bottom). Thus every year the tessellation of the pattern of the soil removal areas was adjusted and updated according to new evidence. Nearly always the space allocated to archaeology ranged between 5-6% (Table 3).

Table 3: Proportion of the study area allocated to polygons

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Archaeological</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>polygons</td>
<td>5.47%</td>
<td>4.21%</td>
<td>5.73%</td>
<td>5.30%</td>
<td>5.48%</td>
</tr>
<tr>
<td><strong>Non-archaeological</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>polygons</td>
<td>94.53%</td>
<td>95.79%</td>
<td>94.27%</td>
<td>94.70%</td>
<td>94.52%</td>
</tr>
</tbody>
</table>

Year 2005 was just the second year of the project and therefore the 189 digs of the database could be compared with only 160 of the previous year, among which only 16 sites signaled some evidence of archaeology. As a result there is a poor cover of the archaeological digs of 2005 by the archaeological tessellation of 2004. Only 1/3 of the archaeological sites sit on the territory of an archaeological dig of 2004. Yet the distribution of digs in 2005 is not totally random with respect to what we know from 2004. Indeed only 9.70% of the non-archaeological digs sit on archaeological polygons of 2004. Had it be random equal or nearly equal percentages of archaeological and non-archaeological digs would be scattered across the two types of polygons. Moreover, the overall percentage of “right predictions” is as high as 82.54%. The area covered by archaeological polygons of 2004 represents 5.78% of the total area.

 Apparently, the archaeological tessellation of one year is by no means sufficient. As soon as more data were introduced in the database, the picture became clearer. The following year the building activity increased and 370 sites in Patras are recorded to have suffered from soil removal, 21 sites
more than all the sites of both 2004-2005. Despite the proliferation of numbers, the location of the sites tend to comply with the formed pattern of 2004-05 Thiessen polygons. Out of 68 archaeological digs, 77.94% sit outside archaeological polygons and 4.3% of the non-archaeological digs.

Figure 2: Voronoi tessellation and the distribution of digs within the City Plan of Patras
digs are to be found inside archaeological polygons. If one would expect all archaeological digs to reside in archaeological polygons and all the rest to be outside of them, then one would have guessed well for 22.06% of the archaeological digs, 95.70% of the non-archaeological digs and for 82.16 in total. In 2007, third year of the application, “right predictions” for archaeology rocket to 60%, and the next year they reach 68%. The predictive strength of cumulative tessellation is getting dynamically improved.

Visual inspection was complemented with the employment of statistical tests, $\chi^2$ and Fisher’s, to further test the hypothesis that every year’s new archaeological digs and already established archaeological tessellation are not independently located. The few exceptions of false predictions, though they decrease gradually, needed identification and review. For this reason, a spatial statistic test, Local Moran’s I, was executed, to identify statistically significant clusters and outliers.

![Figure 3: Clusters and outliers defined with Local Moran’s I test](image)

For statistical analysis the data were classified in terms of two criteria (presence/ absence of archaeology in the digs and the type of polygon, archaeological or non-archaeological, in which they lie) and 4 tests were made on how independent the classes are [16, p.70]. Independence of the classes represents null hypothesis. $\chi^2$ test was first employed. The results were not always statistically valid, because expected frequencies were below the threshold of five, a strict limitation
for one degree of freedom. Alternatively, I performed Fisher’s exact probability test, a direct
calculation of the significance probability with no requirements on the expected values, usually
performed when \( x^2 \) is not valid [17, p.197-8, 18, p.160].

Null hypothesis was rejected, and there is extremely low probability that differences between the
two criteria have been caused by chance (Table 4).

Table 4: Fisher’s Exact Probability test values obtained from data in Table 2

<table>
<thead>
<tr>
<th>Criteria</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digs of 2005 and Polygons of 2004</td>
<td>0.014</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Digs of 2006 and Polygons of 04-05</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Digs of 2007 and Polygons of 04-06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digs of 2008 and Polygons of 04-07</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An additional spatial statistic test was employed to overcome the “aspatiality” of the former and
facilitate the data analysis and interpretation at a localized level [19, p.91]. The choice of Local
Moran’s I test was guided by the need to detect clusters of digs with similar values (archaeological
or non-archaeological) and digs with values different from their neighbors, that is archaeological
digs in the neighborhood of non-archaeological ones and vice versa. This type of analysis would
not have been possible with the application of global spatial autocorrelation tests [20, p.856-857].

The resulting index shows that whilst non-archaeological digs form no clusters, the archaeological
digs are clustered (Figure 3). The clusters correspond to the archaeological pattern configured by
tessellation (Figure 4). However, 11 archaeological digs were surrounded by non-archaeological
ones and 44 non-archaeological digs were inside or very close to archaeological clusters. The
existence of statistically significant (0.05 level) outliers both archaeological and non-archaeological,
intrigues for further study and interpretation in conjunction with background contextual
information.

RESULTS & DISCUSSION

There is clearly not a random distribution in the archaeological digs and there are clear clusters of
archaeological digs in the area. (Figures 1, 3). The study of the digs in Patras concerned only the
ground disturbance sites of the period 2004-2008. No notice of the known archaeological profile of
the city was taken, as if there were no archaeological research before. Naturally, that is not true.
Numerous excavations have taken place. Numerous archaeological deposits have been discovered
over the years. The majority of excavations have not been published, due to workload and
researchers’ copyright. Still several synthetic papers have attempted to reconstruct pieces of the
palimpsest below the modern buildings [21, 22, 23, 24]. As a result the topography of the ancient
settlements and the operating functions are documented at a diachronic scale.

It is possible, therefore, to compare the results of the application with prior knowledge and see to
what extent they fit. Already the tessellation of 2004 gives insights of the archaeological profile.
The configuration of the archaeological polygons changes as more digs are included. It is worth
noting that even though the tessellation of 2004-8 was made up of 941 digs, the archaeological
space they occupy still accounts for the 5.48% of the total area, a proportion equal to the proportion
of archaeological space in 2004 which contained 160 digs (Table 3). Every time the dataset increases,
lesser space is allocated to each dig. The archaeological space becomes more compact and the
boundaries of the pattern are revealed in greater detail. Special function areas and outliers begin to show up like islands.

Figure 4: Potentially archaeological territory within the City Plan of Patras, after cumulative Voronoi tessellation of years 2004-8

Let us concentrate on the Figure 4, since these archaeological polygons represent the culmination of the application in so far. The habitation and activity areas of the Classical, Hellenistic, Roman and Byzantine periods are all detected in the biggest archaeological polygon of the application. Public buildings and private houses, workshops and infrastructure were discovered in the digs. Few burials were also discovered bearing witness of small cemeteries that had operated there [22, p. 63]. The western pieces of the polygon occupy the manufacturers’ zone [24, p.33). From there the line to the northeast that is formed by 6 polygons, 4 closer to the city and two further apart bears witness of one of the three major ancient cemeteries the northern one, along the ancient road to Corinth. Not all digs here have produced burials. However, it is known that outside the city there were several villae rusticae of both Roman and later periods, the owners of which preferred locations near roads, for easy transportation and communication [4, p.95-99, 22, p.60].

The same picture is revealed where the other two major road axes and cemeteries lie, i.e. in the southwest and the southeast. The tessellation of 2004 demonstrates polygons related to the southwestern cemetery. But by 2008 more digs have produced archaeology, such as graves,
building vestiges etc. and more archaeological polygons emerge. That makes sense because this is the area most adjacent to the harbor and a lot of activity and trade transactions took place there [4, p. 95, 22, p.70-71].

The line of the southeastern road that led to the hinterland of Peloponnese and the southeastern cemetery are clearly shown while crossing four polygons. A fifth polygon deviating from the line to the east might well be another villa rustica or a workshop outside the city [4, p. 95, 22, p. 71]. Two polygons to the northeastern edge of the map and one polygon to the east are built in two different zones of prehistoric habitation in the Bronze age [24, p. 6-7, 4, p. 83-84]. The latter is near a bigger polygon at the edge of the City Plan where a Roman road was discovered.

Extra consideration should be given to the 44 non-archaeological outliers inside or adjacent to archaeological clusters (Figure 3). In order to justify their existence it is necessary to confer to the history and documentation of each corresponding dig. Four possible explanations are provided.

1. *Difference in depth of ground disturbance*: e.g. Non-archaeological dig nr 175 is near the archaeological dig nr 682. The former was dug to the level of 1m. below the surface, while the latter revealed archaeology at the level of 1.4m.

2. *Proximity to an artificial cluster*: e.g. Non-archaeological dig nr 632 is near an archaeological cluster. The cluster is “artificial” in the sense that all digs comprise one extensive linear ground penetration along a modern road superimposing a Roman one. In this case more digs and excavations will shed light on the archaeological potential of the neighborhood.

3. *Destruction of archaeological record at some earlier time*: Needless to say that the majority of the non-archaeological outliers belong to this group. Continuous habitation of the old town of Patras along with natural and man-made destructions throughout the centuries have resulted in the elimination of archaeological deposits.

4. *Insufficient documentation and lack of synthetic publications*: The fact that documentation of the digs started only recently, for other than research purposes, is to blame, as well as the sparse and undetailed publication of excavations for an unidentified and unpredictable number of outliers.

**CONCLUSIONS – IMPLICATIONS FOR THE FUTURE**

Digs can provide a quick and functional way to record the archaeological palimpsest buried underneath modern cities. Recording and statistically processing information generated by the digs of five consecutive years can significantly contribute to the configuration of a predictive archaeological model of a city even if no prior knowledge is considered. Voronoi tessellation, conventional statistics and spatial autocorrelation tests may complement each other and enhance the predictive potential of each one separately. Complementary use of background contextual information and continuous updating of the dataset with more digs can minimize the frustration that unexpected outliers cause.

In this way, maps of the archaeological potential of the city are readily available and disseminated to interested users, without intervening to archaeological activity and without affecting research copyrights. Investors, developers, landowners and planners can have a handy tool to evaluate the archaeological potential of land and adjust their plans. Moreover urban planners can contribute their skills in integrating an archaeologically informed approach to general schemes of urban development and land use. Besides, the fact that the proportion of archaeologically potential land never exceeded 6%, even though the sample quintupled in the course of the years, facilitates development and conservation programs. Cultural heritage management, as exercised within
Archaeological Service can be enhanced because it can control expected and unexpected resources, assess common practices, detect positive or negative correlations between resources and propose conservation. Close collaboration with urban planners is necessary for the implementation of such programs.

Judging from the degree to which the picture of the archaeological pattern is improved each time the dataset is updated, this research will benefit immensely if more information enters the dataset, whether it includes digs before 2004 and/or digs after 2008. There have been proposed but a few basic applications of the spatial analysis of the urban dig reports that archaeological and city planning units should keep. The only characteristic I used for analysis was the presence/absence of archaeology in each dig, but the reports contain a few more (depth, type of soil, duration of excavation), which combined with other types of information (chronology, artifacts etc), deriving from excavation diaries are suitable for more sophisticated applications in the field of Geographical Information Systems and Spatial Technology. Such applications involve the analysis of space as a continuous surface, and are suitable for estimating density of data and for 3D modeling [25]. However, their use depends on the availability of original data, currently missing or kept undeveloped in curators' desks.

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