AORISTIC ANALYSIS: SEEDS OF A NEW APPROACH TO MAPPING ARCHAEOLOGICAL DISTRIBUTIONS THROUGH TIME

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ABSTRACT

Aoristic analysis generates a temporal probability distribution from a spatially located population of temporally imprecise events. It is used, for example, in analysing burglaries, where only the terminus post quem and terminus ante quem of events are known, but not their actual time of occurrence. Chronological determination of artefact dating based on typology and/or attributes shares similar characteristics, in that we often know the range of dates over which the artefact could have been produced, but do not know its date within that range.

This paper considers the potential of aoristic analysis to provide probabilistic statements about the dating of assemblages, and its potential for extracting dating information from the full range of material, not just chronologically specific items which may occur rarely. The ability to combine narrowly dated characteristic artefacts with long-lived generic forms, should particularly suit mixed assemblages, such as those encountered in archaeological surveys.

The use of aoristic analysis is illustrated through an application to chronological identification of pottery from the Australian Paliochora-Kythera Archaeological Survey (APKAS), which shows how it might be used to map the changing pattern of artefact distribution through time.

It is also proposed that the concept of distributing probabilities through time might be extended further to cover spatially distributed assemblages of features, such as urban settlements, where there are multiple, potentially conflicting, sources of dating information. In this way we may be able to build accurate if fuzzy pictures of spatial distribution through time in place of representations which hide our uncertainties under a false appearance of precision.

INTRODUCTION

One of the fundamental problems in analysing the results of archaeological field surveys and in studying prehistoric settlement patterns, is the difficult question of ´contemporaneity´. Unfortunately - at least for archaeologists - Pompeii-style events are the extreme exception, and most of our evidence consists of palimpsests of the products of overlapping activities built up over years, centuries or millennia. Without a knowledge of the contemporaneity, or otherwise, of archaeological structures and discarded materials, discussion of landscape use and settlement patterning - so fundamental to much archaeological interpretation - often depends on convoluted arguments or, in some cases, simply conjecture.

For typical 'fieldwalking' surveys, a proportion of the material observed can be allocated to date ranges (generally determined - more, or less, narrowly - by pottery styles or stone tool technology). We generally make the assumption that there is not too much 'fossil' deposition, and that material deposition equates with activities (which can of course include secondary redistribution through e.g. manuring). For archaeological sites within a landscape or built structures in settlements, the dating imprecision is further complicated by their potential for long-term use and re-use.

The challenge is to work back from a loosely dated assemblage of objects - whether artefacts, structures or sites - to some estimation of the pattern of occupation in the past, and if possible to an understanding of the changes in occupation pattern, since it is on this information that so many archaeological theses are built.

APKAS: A CASE STUDY

In the Australian Paliochora-Kythera Archaeological Survey (Johnson and Wilson 2003, Coroneos et al., in press), our attempts to quantify settlement patterns from intensive field survey results - in order to examine postulated depopulation of the island - have been frustrated by small numbers of precisely datable artefacts and the limited scale of the survey. Even with larger samples, the interpretation of settlement patterns from archaeological field surveys in the Mediterranean, as elsewhere, is often subjective, since we do not have appropriate tools for quantifying and analysing temporal spread, least of all when this is combined with spatial distribution.

The specific result we require from the Kythera survey is quantification of the change in settlement pattern to test the hypothesis of periodic abandonment of marginal environments - most specifically around the period of the sack of Paliochora (AD1537) - and to determine whether the 'fossil' distribution of churches (more than 80 for less than 1,000 present-day inhabitants, many isolated from villages or other habitation) reflects the former distribution of activities.

The Problem with Time

In my original proposal of the TimeMap methodology at the 1997 CAA Conference (Johnson 1999) I sought ways of explicitly recording the temporal signature of spatially located archaeological and, more generally, historical phenomena. These included the recording of 'snapshots' at known times, defining ´terminus post and ante quem´ dates, and defining spread of uncertainty in dating as a through-time function.

The fundamental problems faced in satisfactorily recording historical phenomena include: 1. dating, even of individual events or objects, is generally only to within a loosely defined time range; 2. cultural areas - however defined - are not static objects which appear full-formed and disappear instantly; 3. cultural phenomena are generally not spatially uniform as demanded by most vector GIS data models, and we often do not know much about their internal pattern; and 4. our knowledge of spatio-temporal objects is typically anecdotal 'snapshots' of their extent at more, or less, accurately known times.

Figure 1 Contributions of different events/objects to aoristic weighting (areas of rectangles in upper diagram are equal, representing 1 object)

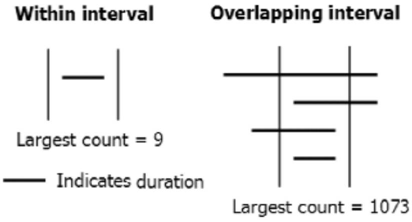


Figure 2 Alternative methods of determining object counts for a specified time interval (2a - left. diagnostic objects; 2b - right. all potential objects)

There is a difficult balance to be struck between adequately capturing the information available, and making the recording of such information unrepeatable and impossibly onerous. To my knowledge no-one has proposed a generalised method appropriate to archaeological material, although much research has been carried out - generally with an emphasis on contemporary data - into temporal databases (e.g. Tansel et al. 1993) and, to an increasing degree, spatio-temporal databases (e.g. Yuan 2001), and there are numerous domain bibliographies (e.g. Roddick et al. 2001).

Aoristic Analysis

Aoristic analysis (Ratcliffe 2000) is a method which is applied to the analysis of crime incidents. Archaeological events - such as the deposition of an artefact or the building, use and abandonment of a structure - share some of the characteristics of crime incidents: we normally know their location with some accuracy, but can only locate them temporally between a terminus post quem (the last known pre-incident moment or, for artefacts, the start of the known period of production of the artefact) and a terminus ante quem (the moment when the incident was discovered or, for artefacts, the likely end of production and/or deposition). Aoristic analysis has the potential to address some of the problems encountered in analysing spatio-temporal archaeological data by providing us a means of dealing with the variation in precision of dating of different types of artefact, from 'diagnostic' items to generic pottery or waste flakes.

In aoristic analysis, the probability of each event is distributed evenly across the time span during which it might have occurred. The probability of all events is the summed probability of individual events; events with tight temporal definition contribute more to the total probability over their range than do loosely defined events.

Figure 1 illustrates the way in which five objects/events of different temporal extents contribute to the overall probability. Note that, although the probability of an object/event occurring in a given time interval is higher in the second peak than in the first, the sum of probabilities (represented by the area under the graph) for the first peak is approximately three times that of the second.

The aoristic approach of distributing probability across the possible temporal range of a crime incident, can be applied to archaeological material by distributing artefact or feature weighting across a time period identified on stylistic or other dating grounds. Where the time range is sharply defined (e.g. short-lived and easily recognised wares), the weighting is high, creating local evidence peaks - a 1950s building is stronger evidence for activity in the 1950s than a generic neoclassical building is evidence for activity in the 1850s (or indeed, in any other decade). Non-uniform distribution of weighting can also be applied if there is an ´a priori´ reason such as additional knowledge about particular artefacts or periods from other sources.

There are of course alternatives methods for allocating objects/events to time intervals. Classically one would count the number of artefacts which fall within each time interval (Fig.2a), and the intervals themselves would be of different durations defined differentially in terms of perceived 'periods' recognisable from the artefacts. As well as being a slightly circular argument, this method does not allow for different degrees of temporal resolution in temporally overlapping artefacts. The problem is that if the interval is defined narrowly enough to provide temporal discrimination, very few objects/events will fall in the interval and the bulk of less 'diagnostic' objects will not contribute to the result.

On the other hand, if we count the number of objects which might have existed in a particular interval (Fig.2b), i.e. all those whose time range overlaps the interval in question, the

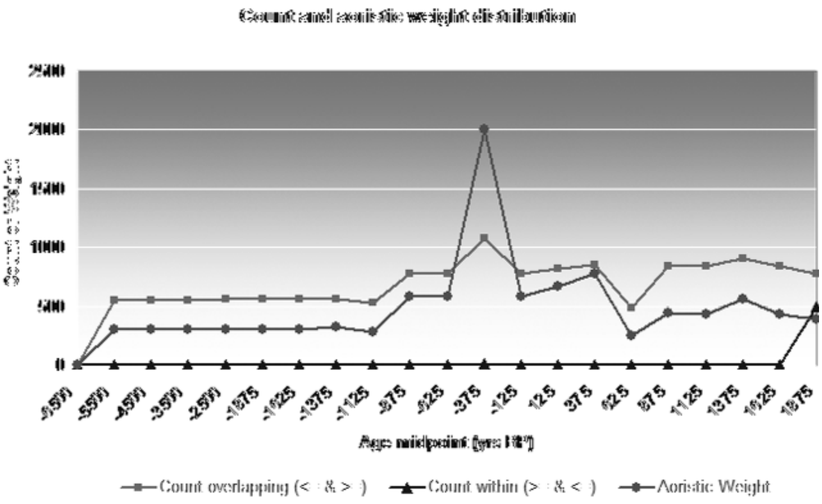


Figure 3 Kythera preliminary data: temporal discrimination of aoristic weights (circles) compared with distribution of temporal marker artefacts (triangles)

contribution of tightly dated 'diagnostic' pieces is swamped by the mass of undiagnostic material of indeterminate date.

Aoristic analysis steers a middle ground by attempting to weight material according to the strength of information that it contributes, and thus maximise the use of available information to define through-time variation from sparse data.

Aoristic Analysis and Spatial Distributions

The ability to make use of all available information is particularly critical when one wishes to look at the spatial distribution of activities or occupation. While there may be enough diagnostic pieces to describe the overall distribution of occupation through time for a study area, the division of a study area into spatial units imposes the need for a much larger sample if we are to define shifting activity foci. By combining the information from 'type specimens' with more loosely defined finds categories, aoristic analysis increases the effective sample size by sacrificing temporal precision for temporal pattern.

I have applied the aoristic approach, with some limited success, to preliminary data from the Kythera survey. The data available represents only a small part of the survey and reveals the need to systematically apply identification to all the survey material collected in previous seasons. We hope to complete identification of the backlog of collected material during the 2004 field season, allowing it to be incorporated into the analysis.

Figure 3 shows the distribution of aoristic weight (circle markers, highest peak) compared with a simple count of artefacts which have time ranges overlapping each interval (square markers, lower peak) and a count of artefacts distinctive enough to be identified to a time interval (triangle markers, merging with the X axis). The aoristic weight emphasises narrowly dated artefact types without ignoring the 'background' of less diagnostic pieces.

Method

We divide the overall time frame of the material recorded into equal intervals. In the case of Kythera, for example, we have a time range from a notional 10,000 BCE to 2,000 CE, which we have divided into arbitrary 100 year intervals. The artefact is allocated a weight, calculated as:

Aoristic Weight per interval = Interval Size / Time span for artefact type

for each interval which lies within the possible time span of the artefact. The weight is thus highest for artefacts with a limited potential time span ('diagnostic' artefacts) as opposed to generic artefacts which could have been produced and/or deposited over a wide range of time. For example, an artefact which can be identified to a 200 year time span will have a weight of 0.5 in each of two 100 year intervals. An artefact which might have been produced anywhere within a 2,000 year time span will have a weight of 0.05 in each of twenty 100 year intervals.

The time span for each artefact is determined from its identification to a 'chronotype' (see Given et al. 1999; examples of chronotypes are given below). Chronotypes are assigned a period, ranging from quite specific dating (e.g. Early Helladic IIIb) to a very wide range (e.g. Pre-Ceramic). The chronotype identifier is used as a foreign key to a table of periods, which in turn provides the time span for the chronotype, and hence the artefact. For example:

Narrow dating:

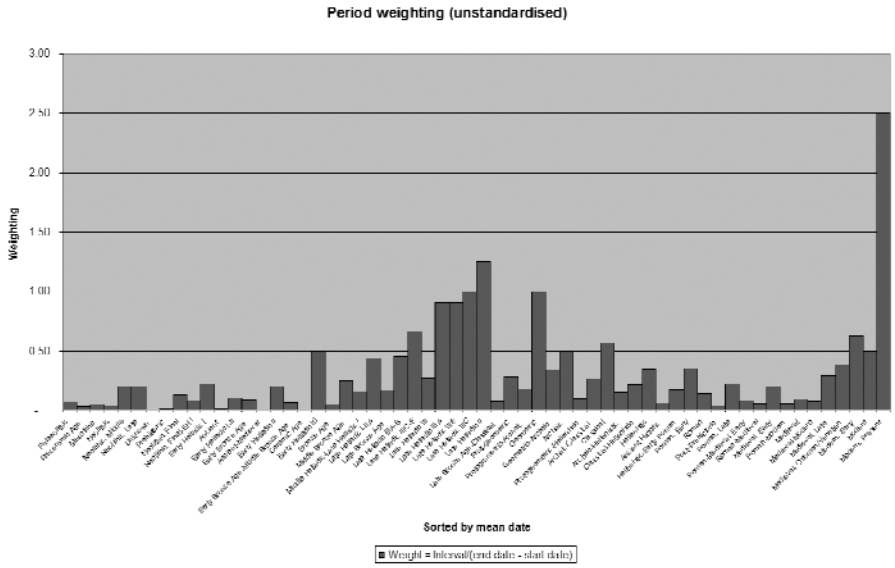
> Chronotype (allocated): Amphora, Smyrna Jar
> Period (derived from chronotype): Mediaeval, late
> Dating (derived from period): 1200 - 1537 CE

Broad dating:

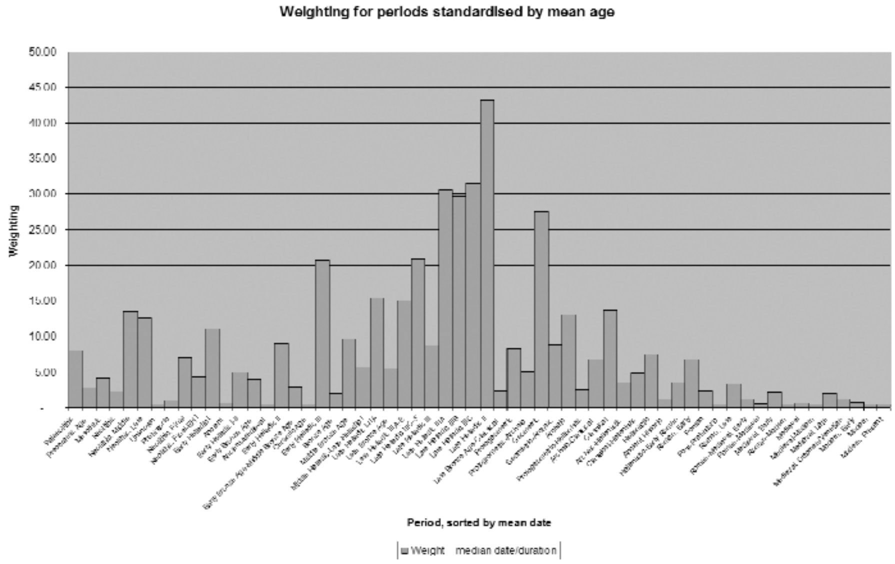
> Chronotype (allocated): Pithos (undifferentiated)
> Period (derived from chronotype): Ceramic age
> Dating (derived from period): 6300 BCE - AD2000

The problem with equal weighting of time intervals is that historical time does not operate to a uniform scale. The upheaval of the industrial revolution is below the resolution of dating for the later Palaeolithic. Like an expanding universe, time draws out as one goes further from the here-and-now, artefacts become scarcer and the information available becomes thinner and less diagnostic.

To use equal time intervals and weightings based on them would seriously skew the analysis in favour of recent periods, where artefacts can be placed within a few years or decades. Even quite generic modern artefacts will achieve weightings of 0.5 - 1.0, whereas the most distinctive Palaeolithic artefacts would rarely achieve a weighting of 0.1.



Figures 4a, 4b The effect of standardizing aoristic weights for pottery identification periods by median age of period. Horizontal axis: ranking by median age. (4a - unstandardised, 4b - standardized)



In order to counteract this tendency I used a simple correction which consisted in dividing the median date of the period, rather than the size of the intervals, by the length of the time span. Standardisation by age highlights 'better than expected' dating discrimination, such as the various phases of the Late Helladic (central peak of Figure 4b), each lasting only a couple of hundred years. However the values no longer reflect the total of probabilities (0 through 1) for the artefacts observed, but are instead greatly amplified.

A better scheme would have been to increase the size of intervals in proportion to age and to allocate probabilities equally between intervals irrespective of absolute duration. The results of the correction are shown in Figure 4b, which show the substantial emphasis created for narrowly dated prehistoric periods.

The preliminary analysis of Kythera was carried out using simple MapInfo SQL and MapBasic instructions to generate a series of calculated fields and apply thematic shading. The Finds, Chronotypes and Periods tables were joined to generate time ranges and aoristic weights for each find, and the weights were then summed for each survey unit for each time interval. Finally the survey units were shaded on the map according to the sum of the aoristic weights for the time period in question.

Two preliminary maps are shown in Figure 5 to illustrate the very provisional results of this analysis. It is worth noting that the despite use of the aoristic technique, the discrimination provided by more diagnostic pieces has been largely swamped by the effect of undifferentiated coarse pottery, which could date to anywhere in the last 8,000 years. In future analyses we will remove this hugely overwhelming body of material.

FUTURE DIRECTIONS

The aoristic approach discussed in this paper accommodates a single method of dating - in this case temporal ranges derived from (primarily) pottery identification. It cannot at first sight accommodate multiple sources of (potentially conflicting) dating which might be encountered, for example, in analysing an assemblage of structures in an urban context. However the allocation of probabilities across time ranges has potential as a means of tackling more complex problems.

For the pre-industrial city of Angkor (Pottier 1999, Fletcher 2001), systematic recording of more than 2000 Angkorean period settlement structures (temples, tanks, house mounds, canals and reservoirs) derived from analysis of airborne radar (Evans 2002), is uninformative on contemporaneous settlement patterns or settlement pattern change through time. However there are many sources of dating information, including inscriptions, feature style, surface finds, coring, stratigraphic relationships and spatial relationships. Using these sources we aim to build a probabilistic web of dating evidence which will combine aoristic analysis of datable artefacts with building styles, stratigraphic relationships of features and spatial associations between features.

Critical to the success of this approach will be the incorporation of stratigraphic relationships between features, defined through observation of their intersection and spatial relationships. Stratigraphic relationships have been widely exploited in archaeological excavations - explicitly identified and analysed since the 1970s using the Harris Matrix (Harris

1979) - and play an implicit role in the analysis of rock art (e.g. Taçon et al. 1996), but have not to the best of our knowledge been systematically applied to spatially distributed archaeological remains at a settlement level.

The eventual aim of these analyses is to generate time series of maps, and to use these maps to answer significant questions about the history of settlement patterns and issues such as depopulation, environmental or economic change. Because the dating evidence is necessarily expressed in probabilistic terms, these maps will not simply indicate a cut-and-dried picture of the layout and density of occupation through time, but will provide a probabilistic statement about what features might or might not have existed at each point in time, or the probable frequency of deposition events through time. The information in these maps may be less hard-edged than we would like, but this simply reflects our real knowledge of the data.

My aim in experimenting with aoristic analysis is to develop a methodology for more reliable assessment of archaeological field survey results and settlement patterning evidence, based not on selective interpretation of observations but on statistical analysis of all available chronological data. This methodology may fundamentally influence the ways in which we interpret palimpsests of archaeological features.

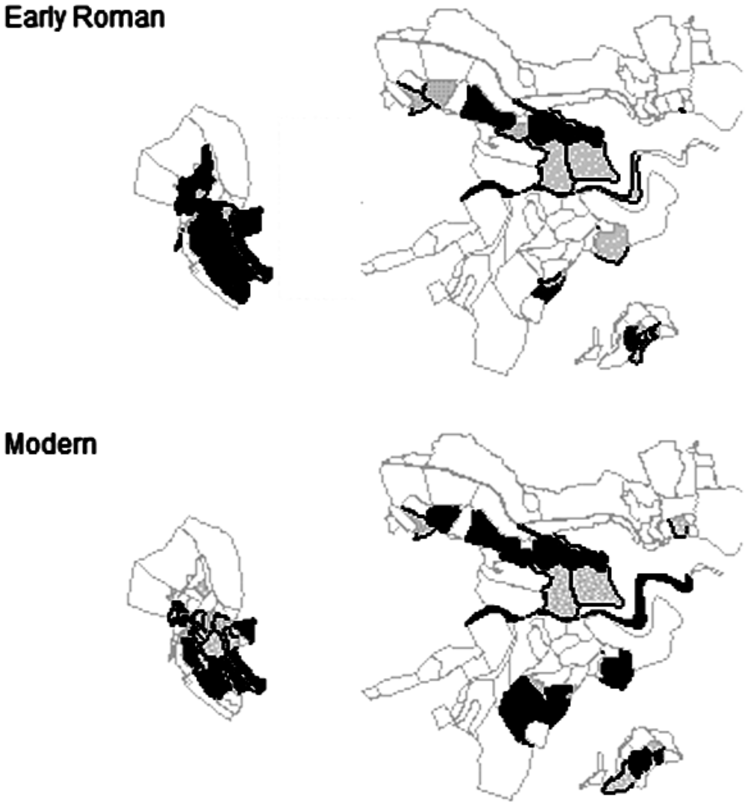


Figure 5: Shift in aoristic weightings between Early Roman and Modern periods: Vythoulas area (left) and Paliochora area (right)

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