mapping prehistoric building structures by visualizing archaeological data and applying spatial statistics

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Revive the Past

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Foreword

The present volume consists of the peer-reviewed papers presented at the CAA2011 conference held in Beijing, China between April 12 and 16, 2011. The theme of this conference was "Revive the Past", which means retrieving our history and using it to help create a new civilization. It was a great honour to organize the conference where over 130 researchers made presentations; ten keynote speeches were given; and sixteen sessions covered a wide variety of topics: data acquisition and recording, conceptual modelling, data analysis, data management, digging with words, 3D models, visualizing heritage sites, digital spaces for archaeology, geophysics, GIS, graphics in archaeology, visualisation in archaeology, semantic technologies, spatial prediction, visualization and exhibition, and 3D object reconstruction. In addition, student papers and posters were presented. We held two successful seminars: "The CIDOC Conceptual Reference Model as a Tool for Integrating Cultural Information" and "Creating Conceptual Models in Archaeology". Two round table discussions were equally stimulating: "The Virtual Silk Road: Reuniting and Recording Scattered Collections and Sites along the Chinese Silk Road" and "Towards an Integrated Geospatial Approach to Archaeological Prospection Data".

As organizers, we want to thank the CAA Steering Committee for their great support and help. We would like to express our special thanks to Prof. Bernard Frischer for his consistent support and kind help. We express our deep gratitude to all participants and delegates for their contributions. We appreciate the generous support given by local institutions in Beijing, and we single out for special praise all of our volunteers for their hard work on behalf of the conference.

CAA2011 has passed into history but we hope Beijing will remain in the hearts of all the participants, especially those from abroad. May the events, people, and friendships made at the conference long remain in our memory!

Mingquan Zhou

Beijing, China, November 2011

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Abstract:
This paper aims to examine the presence of building structures based on the distribution of features and artefacts from a Neolithic site located in Northeast Taiwan: the site of Wansan. Three steps of analysis are conducted. First, we tried to visualize where the buildings might have been located through an analysis of the distribution of postholes. Then, we superimposed maps of the posthole groups, burials, ceramic and lithic artefacts in order to identify possible spatial patterns. Finally, we applied spatial statistics, the Global Moran's I and the Anselin Local Moran's I, to further attest and analyse the presence of these possible buildings. We argue that by using GIS not only different maps can be superimposed easily to facilitate visualisation but also various spatial statistics can be conducted to re-evaluate and confirm the results of the visual analysis which can help archaeologists to construct better interpretation.

Key Words: *Spatial Statistics, GIS, Intra-site Spatial Analysis, Neolithic, Taiwan*

Introduction

This paper examines the possible presence and range of house structures based on the distribution of features and artefacts from a Neolithic site located in Northeast Taiwan - the site of Wansan. Due to the lack of direct architectural remains in Taiwan, archaeologists are reluctant to visualise the presence of building structures, which limits the types of questions archaeologists can ask. However, we believe that archaeologists can do more than hypothesise about the existence of houses. They can identify where the houses might be located and draw boundaries between houses by explicitly examining the spatial distribution of postholes and other features and artefacts.

Since houses are the main living quarters they are the places where archaeologists can learn about early people's daily lives. Accordingly, where houses are located constitutes a focus of research if archaeologists intend to explore early people's daily lives. Most research relies on the presence of architectural structures together with the associated artefact analysis to locate the household units (e.g. Ciolek-Torrello 1989, Gnivechi 1987, Kramer 1982, Leventhal and Baxter 1988, Lowell 1988, Samuel 1989, Smith 1989, Tourtellot 1988). However, most architectural remains are not well preserved in tropical countries such as Taiwan. In order to explore the presence and content of this analysis unit, archaeologists should combine multiple lines of evidence to extrapolate where houses might be located. We argue that the distribution of subsurface features and artefacts should be taken into consideration, especially the presence of clustered postholes. This paper offers an example of how we can "visualise" these houses by analysing distribution of the postholes, artefacts, and other features.

Three steps of analysis are conducted in this paper: visualisation of the distribution of postholes, superimposing maps of postholes, burials and artefacts, and the application of spatial statistics. First, we ploted the distribution of postholes and tried to examine whether these postholes form distinctive groups. Then we superimposed the distribution of postholes, burials, and artefacts on the map to see if we can further differentiate these posthole groups based on their distribution. These posthole groups might suggest the presence and number of possible areas where house structures were constructed in prehistoric times. The final step was to apply spatial statistics to test whether these postholes and artefacts show statistically significant clusters. More importantly, the spatial statistics can take the attributes of certain features into consideration, such as the depth and the size of the postholes. To determine whether specific attributes of the features are clustered or not, we applied two spatial statistics - the Global Moran's I index, and the Anselin Local Moran's I index. The former is used to measure whether a group of features is clustered, dispersed, or randomly distributed; the latter is used to further indicate where the clusters of features with similar attribute values are located (Anselin 1995, 2003; Haining 2003; Moran 1950). Contrary to using statistics to explore spatial association either in a global or local scale (e.g. Haciguzeller 2007; Kvamme 1990; Premo 2004; Whitley and Clark 1985; Williams 1993), we used these two spatial statistics in this study to re-evaluate and confirm the presence of the spatial patterns identified by initial visualisation.

We used a Geographic Information System (GIS) to visualise and analyse the distribution of archaeological features and artefacts from the site of Wansan. We took advantage of its mapping and computing power to superimpose different distribution maps and analyse the patterns more efficiently. In the following section, we begin by introducing the data i.e. the archaeological material from the Wansan

Figure 1. Location of the Wansan site.

site. We will provide a short history of the site and elaborate on the reasons why this site is suitable for this analysis. We will then explain the process of how we identified the locations of the house structures. Afterwards, we will discuss the results of the analysis, and we will attempt to provide a picture of how the early Wansan people might have organised their living space.

Dataset: the Wansan Site

The data for this analysis is from the 1998 rescue excavation at the site of Wansan. The site is located in Ilan County, Northeastern Taiwan (Fig. 1). Several surface surveys and small-scale excavations had been conducted prior to the 1998 excavation. However, the 1998 excavation covered the largest area and unearthed various features and abundant artefacts. The presence of the subsurface features, the amount of artefacts, and the uninterrupted stratigraphy suggest a long-term human habitation in the area. This excavation provided a rich spatial dataset for archaeologists to further explore the distribution patterns.

The 1998 excavation area consists of two blocks: the Northern and the Southern Excavation Areas. The Northern Excavation Area is about 2,000 square metres and the Southern

Excavation Area is approximately 300 square metres. Most of the artefacts and features were recovered from the Northern Excavation Area. Therefore, this paper focuses on the data from the Northern Excavation Area.

Eight types of features were distinguished at the Wansan site, including postholes, stone walls, hearths, storage pits, and burials. We took two kinds of features, postholes and burials, as lines of evidence to infer the number and range of possible house structures. These reasons for this selection are twofold. First, archaeologically speaking, these two types of features are the most abundant and are found all over the excavation areas. Second, ethnographically speaking, these two types of features are often associated with building structures in Taiwanese indigenous societies.

Aside from these features, a considerable amount of ceramic and lithic artefacts were uncovered from the Wansan site. From the amount of lithic and ceramic artefacts we have created a database sufficient for recognising distributional patterns. The total number of lithic artefacts is about 6,000 pieces, including tools, ornaments, unfinished products, possible broken tools, debitage, and raw material. In addition, ceramic artefacts, which consist of vessels, bracelets, spindle whorls, figurines, and some unknown artefacts, amount to more than 370,000 grams.

Analysis

Three steps of analysis were conducted in order to determine the possible number and boundary of areas where the building structures might have been constructed. To begin with, we tried to visualise the presence of building structures by analysing the distributional patterns of postholes, burials, and lithic and ceramic artefacts. Then we employed the spatial statistical program embedded in the ArcGIS software (using the 9.3 version of ESRI's ArcGIS) to test whether these spatial patterns are statistically significant. The use of spatial statistics can not only offer us a way to confirm the visually identified patterns, but can also further enable us to plot posthole and artefact clusters based on the their attributes (e.g. Premo 2004).

Visualisation

The first step of the analysis was to identify the locations where structures might have been constructed by analysing the spatial distribution of postholes. According to ethnographic work conducted on the indigenous societies' dwelling structures in Taiwan during the Japanese colonial period, there are three types of "traditional" dwellings: the pile-dwellings, the ground buildings, and the semi-subterranean dwellings (Chijiiwa 1960; Tu 1998). No matter what types of buildings are constructed, wooden posts are the basic, common component in all the three types of structures. After setting up wooden posts as the main structural framework, different types of materials were used to assemble each dwelling. Therefore, when posthole groups are identified from archaeological sites they can be considered as one line of evidence for the existence of building structures.

In addition, close association between postholes and burials at the Wansan site was noticed during excavation. Ethnographically speaking, placing burials in proximity or directly under residential houses is a common tradition among Taiwanese indigenous people (Chiang 1999; Huang 1982). Taiwanese archaeologists had also documented similar practices at several archaeological sites (Chen 1994; Lien 2003; Tsang et al. 2006). Accordingly, the distribution of the burials at the site of Wansan can be used to imply possible locations where buildings might be constructed. Thus, we superimposed the maps of the postholes and burials to explore possible presence of buildings visually. Since the postholes are direct evidence of the

Distance between posts (m)	Number of cases in ethnographic data
0-0.5	5
0.5-1	2
1-1.5	5
1.5-2	8
2-2.5	2

Table 1. Distance between posts of traditional buildings in Taiwanese indigenous societies (Chijiiwa 1960).

presence of buildings, we began by illustrating where the posthole groups are located. A group of postholes implied the presence of building structures at that locale.

The ethnographic data demonstrate that the distance between posts of Taiwanese dwellings ranges from 50 to 200cm (Table 1) and most of them are between 100 and 200cm apart. Thus, by plotting the postholes on a map and using 100 to 200cm as a possible distance between the posts, we should be able to identify several posthole groups. We can then overlay the map of burials on the map of the posthole groups to see if it is consistent with the ethnographic examples.

Furthermore, we mapped the lithic and ceramic artefacts on the map of the groups of postholes. The purpose is to see whether prehistoric Wansan people discarded their daily refuse in certain locations and whether there is any relationship between these locations and the house structures. In this way we can further consider prehistoric people's behavioural patterns.

Spatial Statistics

Lastly, we applied two spatial statistics, the Global Moran's I and the Anselin Local Moran's I, to see if these visually identified posthole groups are also statistically valid. The Global Moran's I index is used to measure whether a group of features is clustered, dispersed, or randomly distributed (Anselin 2003; ESRI.com 2011a; Wong and Lee 2005; Mitchell 2005; Moran 1950). The Global Moran's I is not only computed by the distance between the features, but also by taking the attribute of the features into consideration. This spatial statistic tool in the ArcGIS can calculate the Global Moran's I index value as well as a *z score*. The I index value is computed as follows:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2}$$

The z_i is the deviation of an attribute for feature *i* from its mean, and $w_{i,j}$ is the spatial weight between feature *i* and *j*, *n* is the total number of features, and S_0 is the sum of all the spatial weights.

When the I index value is near +1.0, it usually indicates that these features are clustered. On the other hand, when the value is around –1.0, then the features tend to be dispersed. Moreover, the Moran's I tool can calculate a *z score* and *p-value* to illustrate whether or not the null hypothesis can be rejected. In this case, the null hypothesis states that the feature values are randomly distributed. The *z score* is the number of standard deviations above or below the mean of its distribution that assist us in deciding whether to reject the null hypothesis or not. It is a measure of standard deviation. The *p-value* is the probability measure that indicates we falsely rejected the null hypothesis. Both the *z score* and the *p-value* are associated with the standard normal distribution. Very high or low *z scores* that are associated with very small *p-values* are found in the tails of the normal distribution. Therefore, when the analysis yields small *p-values* and either a very high or a very low *z score*, it indicates that the observed pattern is unlikely to be some version of the theoretical spatial random distribution suggested by the null hypothesis (Anselin 2003; Mitchell 2005).

Accordingly, the radius of the postholes is used to calculate the Global Moran's I index. If the calculated I index of the radius is larger than +1.0 it suggests that postholes of similar size tend to cluster. At the same time, the depth of the postholes is used to calculate the Global Moran's I index to see if it generates a similar cluster pattern.

While the Global Moran's I index is used to examine whether the postholes with different attributes form clusters, the calculation of Anselin Local Moran's I (ESRI.com 2011b, Anselin 2003) can further identify where the clusters of features with similar attribute values are located. Unlike the Global Moran's I index, the Anselin Local Moran's I index can calculate the I value and *z score* for each feature. As a result, each individual feature within the cluster can be examined to see if it is statistically significant. This method is used in the ArcGIS software that can also recognise the clusters that have similar values and mark them as HH, HL, LH, and LL individually on the map. HH means the features are clustered due to their similar high attribute values, while the LL indicates the clusters are formed because of similar low values. Most importantly, the *z* score represents the statistical significance of the index value.

The Anselin Local Moran's I statistic is given as follows:

$$I_i = \frac{x_i - \overline{X}}{S_i^2} \sum_{j=1, j\neq i}^{n} w_{i,j}\left(x_i - \overline{X}\right)$$

$$S_i^2 = \frac{\sum_{j=1, j\neq i}^{n} w_{ij}}{n-1} - \overline{X}^2$$

The x_i is an attribute for feature *i*, and the $\overline{X}$ is the mean of the corresponding attribute. The $w_{i,j}$ is the spatial weight between feature *i* and *j*, and *n* equals the total number of features.

Applying the radius and depth of the postholes to the Anselin Local Moran's I calculation should allow us to re-examine whether each individual posthole inside the visually identified groups is statistically meaningful or not. Supposedly, the same building structure should have postholes with a consistent size and depth. If the I index value of the posthole is not similar to other postholes in the same group, the reason would need to be further explored based on the contextual information.

Moreover, the distribution of lithic and ceramic artefacts is calculated to see if these artefacts also form clusters in a statistical sense. Most importantly, the Anselin Local Moran's I index can indicate where the artefact clusters are located. The information can be used to confirm the distribution patterns identified by visual inspection.

In sum, the Global Moran's I index can inform us of whether these postholes and artefacts are clustered or not, and the Anselin Local Moran's I can further assist us in recognising where the clusters are located. These results can attest to the spatial patterns recognised by previous analysis.

Results

Visualisation

Figure 2 shows the distribution of the postholes and figure 3 indicates the areas of postholes with 1, 1.5, and 2-metre ranges from the centre of each posthole. When 1 and 1.5-metre ranges are used to identify posthole groups, ten groups are suggested: A, B, C, D, E, F, G, H, I, and J. If the 2-metre range is used, only seven groups are formed. Groups B and C are combined to form one cluster, as are Groups G, H, and J. I would argue that ten groups probably represent a more adequate estimation. If seven Groups are considered, then Groups G, H, and J are categorised as one area where a dwelling might be constructed. However, three men-made terraces (Fig. 3) were identified in the excavation

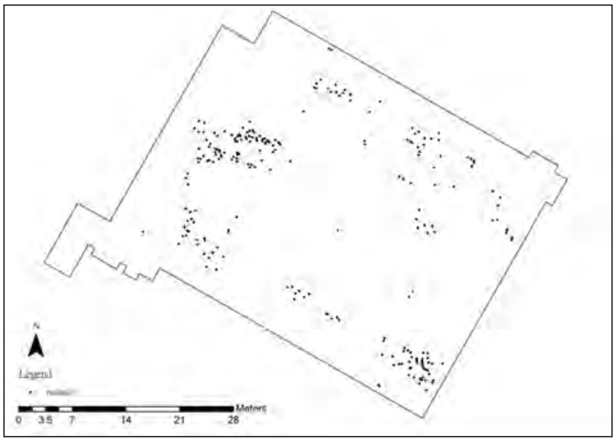

Figure 2. Distribution of postholes.

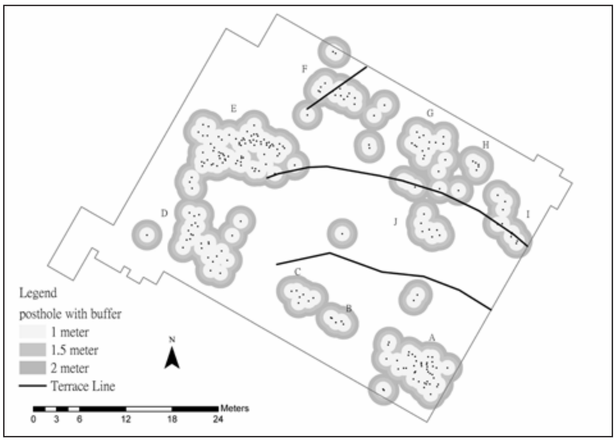

Figure 3. Areas of postholes with 1-, 1.5-, and 2-meter ranges from the center of each posthole.

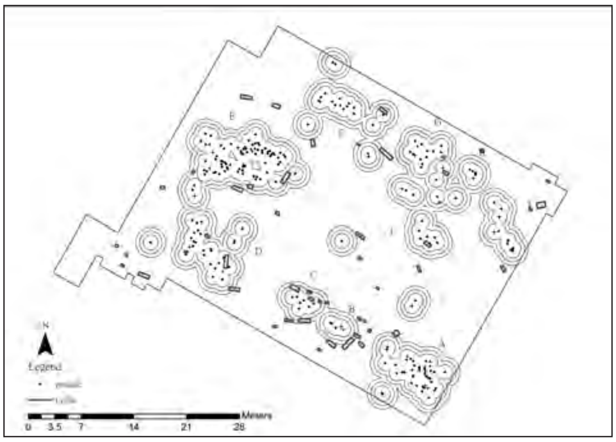

Figure 4. Distribution of stone coffins.

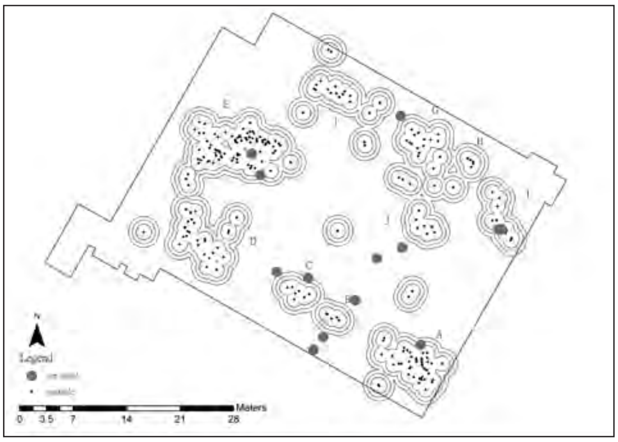

Figure 5. Distribution of jar burials.

Figure 6. Distribution of ceramic artifacts

Figure 7. Distribution of lithic artifacts.

area. Based on this local topography, Group J is on a lower terrace than Groups G and H. In other words, Group J probably cannot form a dwelling with Groups G and H since they are not on the same level as the terrace.

Figures 4, 5, 6, and 7 display the distribution of burials, lithic, and ceramic artefacts with identified posthole groups. There are two forms of burial uncovered from the Wansan site, the stone coffins and the jar burials. The distribution of the stone coffins is closely associated with previously identified posthole groups (Fig. 4). These coffins are all outside the groups of postholes. More specifically, the coffins surround most of the groups. They are either on the edge of the posthole groups or just two to three metres away from the edge of the groups. The distribution of the jar burials is similar to stone coffins (Fig. 5) - one urn burial is situated inside Group E, while the rest of the burials are outside of the posthole groups.

Figure 6 shows the distribution of all the ceramic artefacts along with the identified posthole groups. Since most of the ceramic artefacts are broken potshard, we plotted the total weight of the pottery recovered from each excavation unit on the map. The Group D area shows fewer pottery artefacts due to recent road construction in this area. Therefore, a considerable amount of artifacts in this area has been removed. Most of the artefacts are distributed outside the groups and are concentrated in certain areas. The concentration of pottery in Groups A, B, and C seems to be focused at the northern side; the same is true for Groups G, H, and I. On the other hand, the distribution of artefacts associated with Groups J, E, and F is more likely to be found on the southern side. Figure 7 illustrates the distribution of lithic artefacts in the posthole groups. This map shows the number of lithic artefacts excavated from each unit. The distribution pattern is very similar to the distribution of the ceramic artefacts. Like the ceramic artefacts, few concentrations can be distinguished, and are all closely associated with identified posthole groups.

Application of Spatial Statistics

The Global Moran's I Index calculated from the depth of the postholes is 0.71, the *z score* is 48.41 and the *p-value* is 0.01. In addition, the *i* value calculated from the diameter is 0.08, *z score* is 5.44, and the *p-value* is 0.01. This indicates that the postholes with similar depth tend to form statistically significant clusters as does the postholes with a similar diameter.

Figure 8, 9 and 10 show the results calculated by Anselin Local Moran's *i*. As explained earlier, the calculations of Anselin Local Moran's *i* in ArcGIS 9.3 not only can identify where the clusters of similar values are but it can also classify whether these clusters are high value or low value clusters. Figure 8 illustrates the clusters of postholes along with the visually identified posthole groups. The postholes in the Groups A, B, C, and D tend to form high value clusters, while the postholes in Groups F, G, H, and I form low value clusters. Only postholes in Groups J and F do not form any significant clusters. In addition, Figure 9 demonstrates the clusters calculated from the posthole radius. Only postholes in Group G form high value clusters; the rest of the postholes do not form any statistically valid clusters.

Next, we applied the Anselin Local Moran's I index to indicate the clusters of ceramic and lithic artefacts together with visually identified posthole groups. Figure 10 shows the high value clusters of both ceramic and lithic artefacts. The clusters represent statistically significant clusters in terms of the presence of high numbers of ceramic and lithic artefacts. The lithic and ceramic clusters almost overlap spatially except for the cluster around Group E. Only ceramic artefacts form clusters around this group; the lithic artefacts do not aggregate in this area. The largest cluster is associated with Groups A and B. The other clusters are outside Groups I and J.

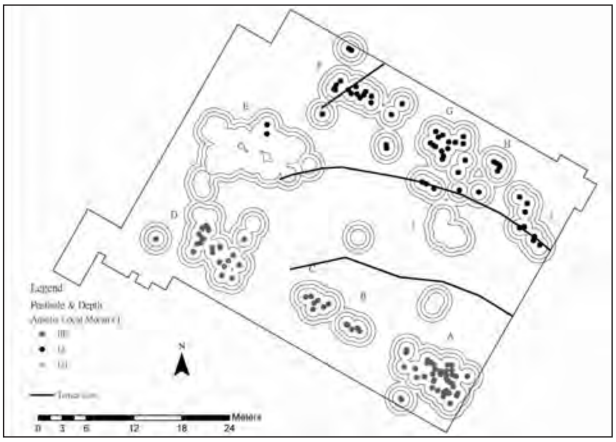

Figure 8. Distribution of postholes with positive i values (Calculated from the depth of the postholes).

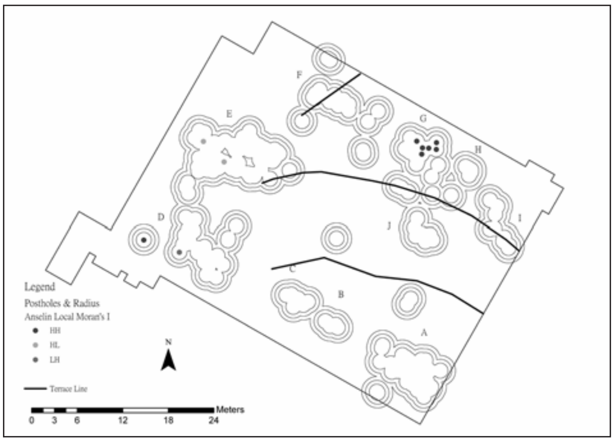

Figure 9. Distribution of postholes with positive i values (Calculated from the radius of the postholes).

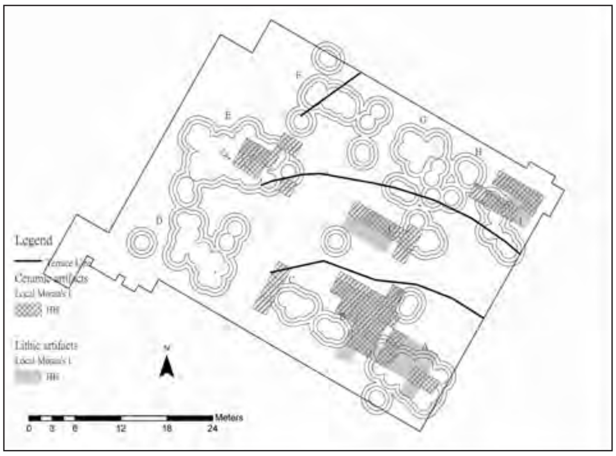

Figure 10. Distribution of clusters of ceramic and lithic artifacts.

Discussion

The main purpose of this analysis was to facilitate the recognition of spatial structures in the excavated area and to further interpret how Neolithic Wansan people organised their space and how this might imply their social relations. Each posthole group can represent a location where a building structure were present; the result of overlapping distributions of the posthole groups, burials, and artefacts suggests that at least ten areas had been used for constructing building structures. In the following section, I will try to explore how people's activities might have resulted in the spatial patterns that we observed archaeologically.

The combined results of these analyses indicate that a few observations of the distribution patterns need further discussion. First is the unusual spatial organisation of the Group E. In general, the spatial pattern shows that most of the burials are located at the edge of visually identified posthole groups. However, one of the jar burials is situated in the middle of Group E (Fig. 5), and since placing the burials at the edge of the posthole groups seems to be a norm, this implies that either Group E enclosed two posthole groups, or the ceramic urn in the middle of the group was not a burial. If the Group E is divided into two smaller groups, then the urn burial is situated at the edge of both groups. In addition, the Anselin Local Moran's *i* values calculated from the depth of postholes show that although the postholes in Group E seem to aggregate visually, the postholes in this locale do not form any statistically significant cluster. One possible explanation for the diversity of posthole depths is that more than one dwelling might have actually existed in the Group E. The area represented with a cluster of postholes of similar depth (i.e., Group A) is likely to have been a single dwelling that was maintained at the same location over time. Thus, the depth of postholes showed a more consistent pattern. On the contrary, the areas with no significant clustering (i.e., Groups E and J) might indicate the presence of more than one dwelling. These lines of evidence suggest that more than one house structure stood in this location.

Second, stone coffins and urn burials are more concentrated on the southern side of the Group J, not surrounding the posthole groups as in other areas. This can probably be attributed to the micro-landscape in this area. Three men-made terraces (Fig. 3) were identified in the excavation area. Therefore, when the Wansan people constructed their houses in the Group J area, they probably built at the north edge of the second terrace and the entrance probably faced southwards to a more open area. Since the back of the dwelling is the natural wall formed by the terrace, it is impossible to place any burials there. Thus, the southern open area constitutes a suitable location for burying their deceased.

Except for this unusual phenomenon, the distribution of features and artefacts show some general spatial patterns that offer us clues about how to approach the question of how Neolithic Wansan people conducted their daily lives. First, postholes tend to form clusters that can be examined visually or statistically. Although the complete building structures are not visible archaeologically, the presence of postholes can be a line of evidence to examine the possible existence of structures in prehistoric societies. Known from ethnographic studies, the wooden posts were often the main construction elements in Taiwanese indigenous societies. Consequently, the areas where postholes are concentrated are probably areas where people built their houses. The identified posthole groups are likely to represent an enclosed area where structures had been constructed, renovated, and rebuilt. Group E, on the other hand, probably represents more than one such area, judging from its unusual distribution pattern, such as the presence of burial inside this group. The calculation of Anselin Local Moran's I index indicates that the postholes with similar depth tend to cluster in this area. However, the situation is not the same if the diameter of postholes is taken into account. Only postholes in Group G form significant cluster. This suggests that when people built their houses the size of the posts were probably not consistent. If the size difference of these postholes is not a result of excavation errors it can probably be attributed to the nature of the house construction. The Wansan people probably built houses by assembling different sized wooden posts and then placed them more uniformly on the ground to keep the house stabilised. Ethnographically speaking, some posts in the Austronesian houses tend to be more important than others (Fox 1993). Thus, it is possible that similar practices were carried out in this Neolithic society.

The formation of artefact clusters denotes that the areas probably had been used as a garbage disposal area. Based on the artefact clusters, the prehistoric people seem to habitually discard their daily refuse in certain areas. The distribution of these artefact concentrations suggests that the Wansan people threw their broken and unusable artefacts close to their building structures. Neighbouring structures might also share the same spaces for discarding their refuse (e.g. Groups A and B).

Conclusions

In areas where architectural remains cannot be found archaeologically, archaeologists need to look for other lines of evidence to demarcate early people's living quarters. In this paper, we employed two main steps in the analysis: 1) visualising the spatial distribution of features and artefacts, and 2) applying spatial statistics to confirm the results of the visualisation and to explore how prehistoric Wansan people might organise their living quarters spatially. Although the initial visualisation of the distribution of features and artefacts already offers several clues to indicate where the Wansan people might have constructed their building structures, the application of various spatial statistics can provide other ways to re-examine the nature of these distribution patterns. By taking advantage of the powerful visualising and analysing ability of the GIS, we successfully ploted and superimposed different maps, and then computed the attributes of these features and artefacts to determine their spatial relationships.

This paper does not intend to provide a method by which to count the exact number of house structures that existed in prehistoric Wansan society because too many uncertainties are involved and too many assumptions need to be made. The lack of architectural structures at archaeological sites in tropical areas has impeded archaeologists from investigating early people's daily life and interactions in the domestic sphere. In this paper, we provided an example of how to use several lines of evidence to explore the presence of buildings in prehistoric times based on the distribution of archaeological material. The presence of posthole clusters - and their spatial association with burials and accumulated artefacts - can demonstrate that the postholes are not randomly distributed and that the identified posthole groups are spatially related to other human activities. The result shows that by analysing the distribution of archaeological data, archaeologists should be able to investigate the presence of structures and conduct further analysis and interpretation.

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