45 Reconstruction of Japanese ancient tombs and villages

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45.1 INTRODUCTION

Visualisation attracts a great deal of attention in archaeology. Many papers on visualisation have already been presented in recent publications (see references). Among them, an important series of works appears to be related to the reconstruction of damaged or distorted monuments. In this approach, the problem we face is how to obtain natural or realistic pictures of reconstructed monuments. In most cases, visualisation has been carried out by computer graphical techniques that include modelling, texturing and rendering. Even today, very much computer power is required to obtain a realistic picture within a reasonable time based on these techniques. Not only computer power but very much labour is also required for this kind of work. In practice we are obliged to compromise over money, time, labour and realism of pictures. Consequently, we have to be satisfied with a picture such as a reconstructed building without the land and sky, or ancient houses without trees. Realism of pictures has unwillingly been sacrificed in a realistic compromise.

Our technical situation may not change dramatically. But there seems to be room for improvement if we can restrict our problems into specialised domains. For example, it will be an efficient approach to focus on a special type of monuments. The present situation appears to be too premature to seek after generality of realistic visualisation.

This paper presents elementary work to improve the realism of pictures based on a standard computer environment: a normal main frame computer, work–stations and peripherals. A specific point is that our work has been done within a specialised domain of visualising two types of Japanese ancient monuments; the Keyhole tomb mounds and the Yayoi villages. Emphasis has been placed on building each individual system to support reconstruction or modelling of a monument.

45.2 VISUALISING THE JAPANESE ANCIENT TOMB MOUNDS

The total number of the Japanese remains recognised as "ancient tombs", from very small to huge ones, is now uncountable. Very many shapes of ancient tomb mounds have been recognised; square, round, scallop–shaped, square–front and round–back (Keyhole–shaped), square–bottom and round–top, square–front and square–back and so on. Among them, the Keyhole–shaped tomb mounds, termed Keyhole tombs, have been regarded as the most important monuments to characterise a period in Japanese history. The Keyhole tombs, in which local leaders or their families were buried, were built all over the country between 300 AD and 600 AD. Even today, more than three thousand Keyhole tombs still remain in the Honshu, Kyushu and Shikoku Islands. As a matter of course, almost all of them have been damaged or distorted over some 1500 years. Unfortunately, a number of Keyhole tombs were even destroyed in recent years during the process of industrialisation or urbanisation that has taken place in many areas.

Reconstruction of the tomb mounds will bring a new impact on many social and scientific fields; conservation of cultural properties, museums, education, publication, TV media and archaeological research. Physical reconstruction is, however, too expensive to be used commonly. Experience from a very few physical reconstructions tell us that a couple of years work and hundreds of million yens (around one million UK pounds) are

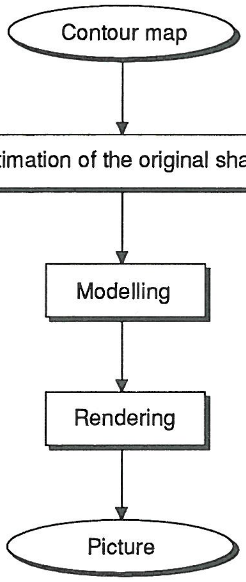

Figure 45.1: Procedure to visualise the Keyhole Tombs.

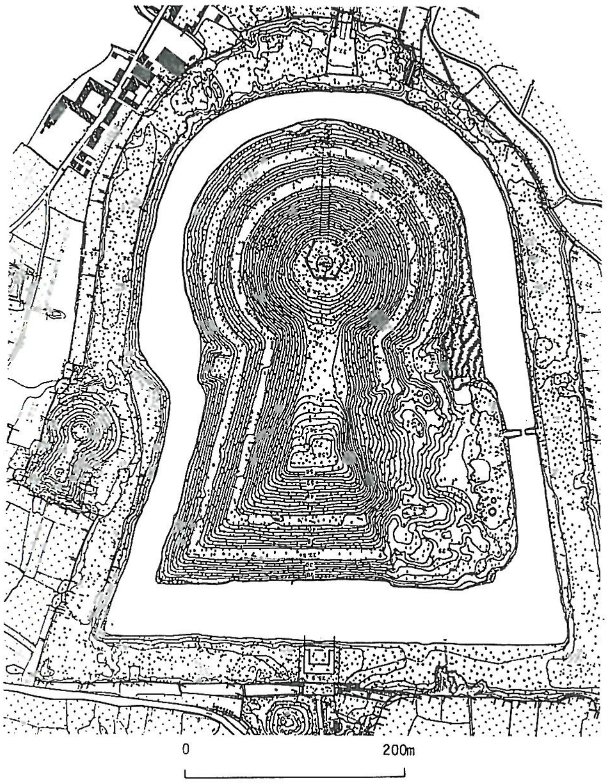

Figure 45.2: Contour map of a Keyhole tomb designated the Mausoleum of the Emperor Ojin. The bottom-right part of the mound has been distorted.

needed for each. A practical way of reconstruction is through visualising reconstruction of Keyhole tombs by computer. Although such computer reconstructions do involve many technical problems, it is much more useful than the physical reconstruction in the sense of portability, duplicatability or revisability.

45.2.1 Procedure

When a damaged tomb mound is given as a subject of visualisation, we currently have no standard guidelines telling us what to begin with and how to proceed to the goal. It is required that we develop a practical procedure for visualisation of the ancient tombs. As a matter of course, computer techniques should be applied as widely as possible to establish the standard procedure. Figure 45.1 shows our tentative procedure to visualise the ancient tombs. The data material to work from is a contour map of a Keyhole tomb mound. The present shape of every tomb mound is more or less distorted, causing a contour map as seen in Figure 45.2. The only way to detect fundamental features for reconstruction of the tomb mound through the distorted contours is to make efficient use of our visual pattern recognition. To support the first stage, estimation of the original shape, an expert system ESRAT has been provided: ESRAT (an Expert System for Reconstruction of Ancient Tombs) creates an estimated contour map of the original tomb mound in co–operation with archaeologists. The second stage, modelling, means the so–called surface modelling of not only the tomb mound but also the surroundings such as a moat, land and so on (See Figure 45.2 or Figure 45.6). The final stage is rendering. In this stage, we face many technical problems related to saving costs and generating realistic pictures.

45.2.2 Expert System

Expertese plays the most important role in reconstructing any archaeological monument. The whole of archaeological expertese can be considered an enormous expanse of continuum. Substantially, it should be impossible to split the expertese into a large number of independent, digitised units. Knowledge engineering seems to challenge us to answer an unsolvable question. Theoretically, this may be true. However, it is also true that useful expert systems have already been put to practical use.

Such an apparent contradiction can be explained as follows: The so–called "knowledge" embedded in a computer is quite different from the experteses and is nothing but very rough approximation of the real knowledge. It follows that every expert system must be more or less incomplete, even if it is practical. Thus, what we should seek is to be build an expert system open to human experts; at any time in the process of inference, the system should consult human experts to aim at perfection of inference. The most reasonable approach to problem solving is by co–operation of an open system and human experts.

From this point of view, our expert system ESRAT has been built for reconstruction of Keyhole tombs. Since the kind of problems met with are not well structured, the machine oriented knowledge embedded in the system is obviously incomplete to handle a variety of examples. To be more precise, ESRAT holds the statistical knowledge for classifying any tomb into the likeliest type and the geometrical knowledge for drawing contour lines of the tomb mound. As mentioned, a contour map of a tomb mound is given first. Since ESRAT can not do visual pattern recognition of the contour map, a human expert does it and estimates the seven dimensions, shown in Figure 45.3, which are accepted by ESRAT. At the first stage, the system classifies the tomb into the likeliest type using the set of dimensions as a basic clue. Currently we have recognised seven types of Keyhole tomb mounds each of which posses common features of shape distinguishing them from each other. The author already established a procedure to identify the type of any tomb (Ozawa 1988). Figure 45.4 presents an analytical chart to identify individual tombs by type. The horizontal axis gives the first principal component reduced from more than hundred sets of the seven dimensions and the vertical axis the second principal component. Shaded domains correspond to the types. When a tomb and its seven dimensions are given, the system quickly computes the position on the chart, identifying to which type the tomb belongs. The shapes of Keyhole tomb mounds, however, can not be determined by the seven dimensions alone: As suggested by Figure 45.2, the shape of the mound includes fine layout patterns; small projections, terraces and so on. Such layout patterns change slightly within a type and grossly over types. The system holds the 17 reference patterns of layout as knowledge, linked to the types. These reference patterns correspond to real tomb mounds symbolically shown in Figure 45.4. The system also detects the nearest reference pattern within an identified type.

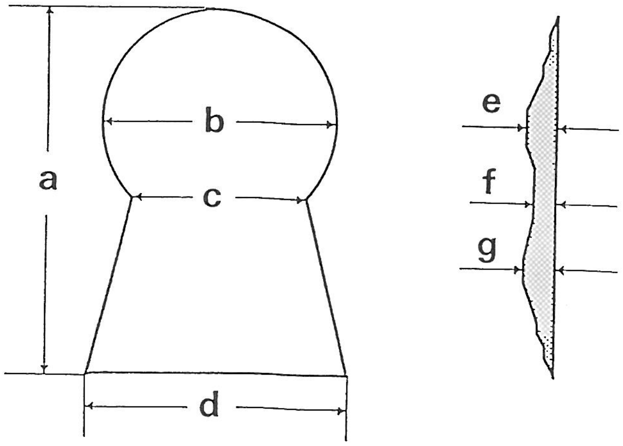

Figure 45.3: The seven dimensions of a Keyhole tomb mound.

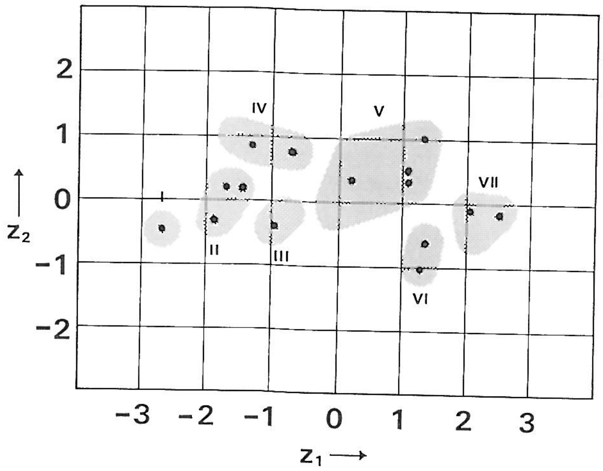

Figure 45.4: Analytical chart to identify the types of tombs. A black dot shows the position of a tomb mound to be referred to as a reference pattern.

ESRAT quickly draws a contour map of a tomb mound being reconstructed according to the estimated seven dimensions and the nearest reference pattern of lay–out. To draw contour lines of a Keyhole shaped mound, many geometrical rules are required. They have also been embedded in the system as knowledge. The system, however, does not always provide a good result. If a tentatively reconstructed mound shown by a contour map can not be accepted, we can make requests to the system to modify the result. Quickly, responding to the requests, the system presents a modified plan of reconstruction. Through such a conversational process, we can reach the goal; i.e. the final contour map of a reconstructed Keyhole shaped mound acceptable for archaeological experts (See Figure 45.5).

45.2.3 Visualisation

ESRAT provides reconstructed Keyhole tomb mounds in terms of contour maps. To visualise them, we have to do still more work; modelling, texturing and rendering. As mentioned, our objective is placed on drawing realistic pictures of reconstructed monuments. Then we aim at com-

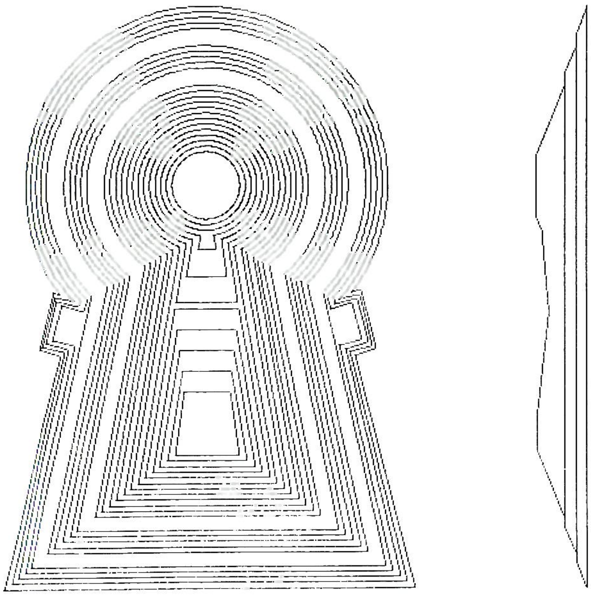

Figure 45.5: Contour map of a reconstructed Keyhole tomb mound drawn by ESRAT.

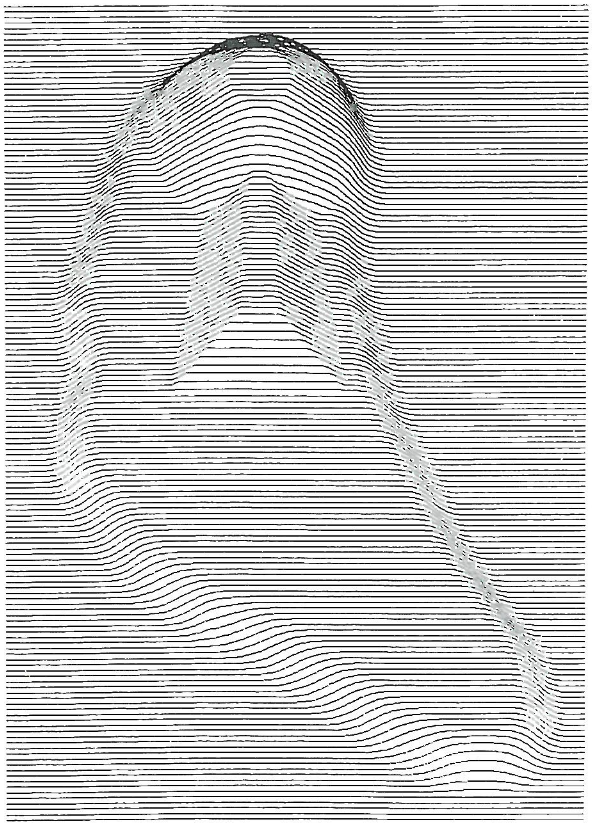

Figure 45.6: Wire frame representation of the surface model of a tomb mound with surroundings (the Hakusan Tomb in Kanagawa Prefecture).

prehensive modelling of the three–dimensional world consisting of not only a Keyhole tomb mound but also its surroundings. In this work, any tomb mound can quickly be modelled with the help of a contour map provided by ESRAT. Modelling of the surroundings, however, require very much labour: All tomb mounds are situated in different topographies. Consequently, for each tomb mound, we have to handle the surroundings individually. In our work, topographical surroundings of a tomb mound have been modelled as a surface composed of very many triangle plane patches. In fact it should be called a hand–manufactured model built by a series of laborious trial and error operations; digitising a topo-

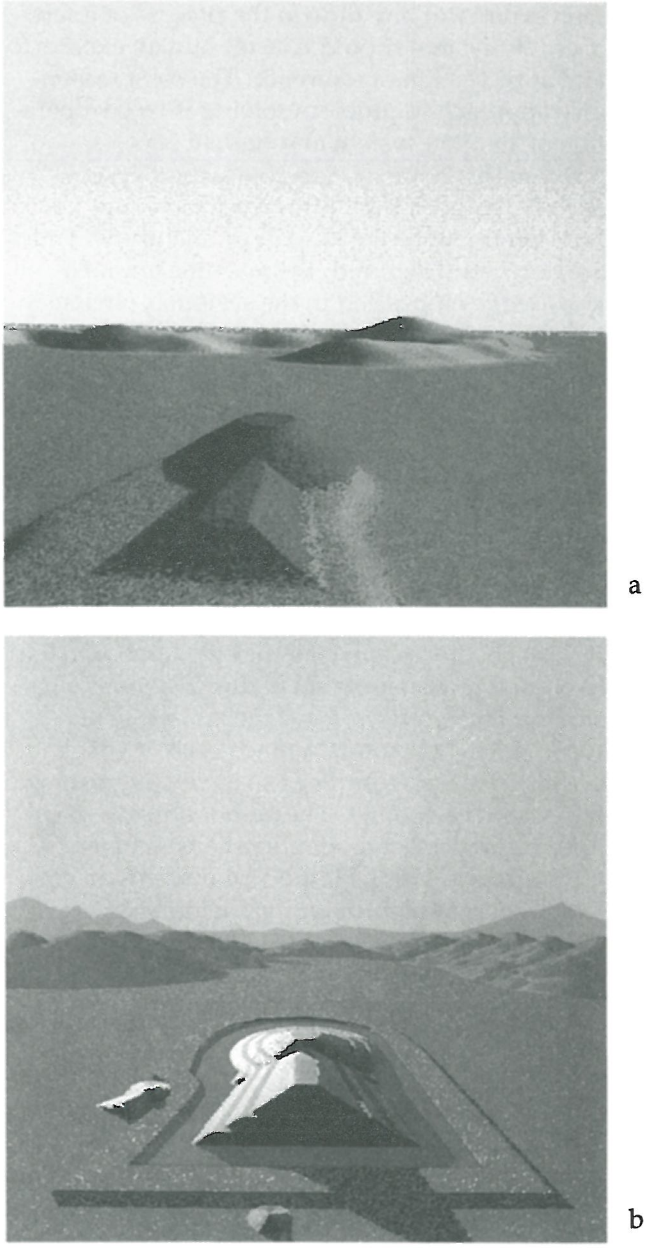

Figure 45.7: Reconstructed Keyhole tombs. a is the Hakusan Tomb in Kanagawa Prefecture and b the Mausoleum of the Emperor Ojin in Osaka Prefecture.

graphical map, defining triangle patches to cover the assumed surface and so on. Figure 45.6 shows a wire frame representation of a surface model of a reconstructed tomb mound with surroundings.

Texturing is also important to obtain realistic pictures. We have introduced a simple algorithm to generate artificial textures mapped onto tomb mounds, lands and mountains: Our algorithm has been embedded in the rendering programme, randomising RGB values on pixels according to the rules defined for all objects with different attributes. This algorithm is, however, so simple that reality of pictures has been fairly lower than expected.

Rendering has been carried out by a ray–tracing programme that requires much computing power, but, theoretically, produce very realistic pictures. A main frame computer VP30E (Fujitsu) was employed for rendering to visualise the Keyhole tombs. Every picture has been given by 700 by 700 pixels, requiring computing times as long as six hours (CPU). The pictures obtained are presented in Figure 45.7; a is the reconstructed Keyhole tomb mound modelled as in Figure 45.6 b is another example.

45.3 VISUALISING ANCIENT VILLAGES

Many ancient villages have been recognised all over the country even by recent excavations. Among them, the Yoshinogari Site in the north–western part of Kyushu Island has been regarded as the most important site involving very large ancient moated villages during the Yayoi Period between 200 BC and 300 AD, spreading out over 40 hectares.

Since all buildings in ancient villages were made of wood, the only straight evidence from which to reconstruct a village is the lay–out of the excavated postholes as shown in Figure 45.8. Although the architecture of buildings is not directly known, a couple of building types have been identified by the lay–out of the postholes, and the architecture of a typical building has partially been suggested by pictures drawn on excavated pottery or bronze bells. Figure 45.9 shows an example of the architecture of a high–floored storehouse as estimated by the evidence.

Not only wooden buildings but also the other objects must be taken into account to obtain a realistic picture of an ancient village: Trees, mountains, forests, moats and so on are important elements from which to compose the picture. In theory, objects belonging to an ancient village scenery could be very many. However, when visualisation is to be limited to a special period, not that many objects are required. It follows that we can aim at building a specialised modeller to visualise ancient villages in the Yayoi Period. The modeller can be sketched as a sort of support system with a database storing a number of modelled objects. In Table 45.1, the expected objects to appear in the ancient scenery are listed, classified into several classes. The present technical situation is, however, very premature to handle all objects in the table. Our modeller as stated below, can handle only a small subset of the table.

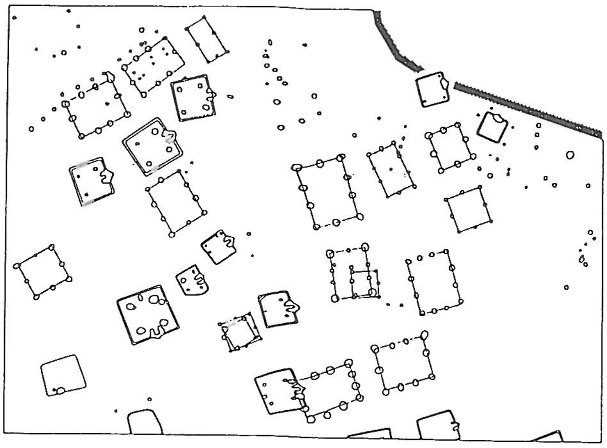

Figure 45.8: Excavated post holes of Yamada-Mizunomi Site in Chiba Prefecture.

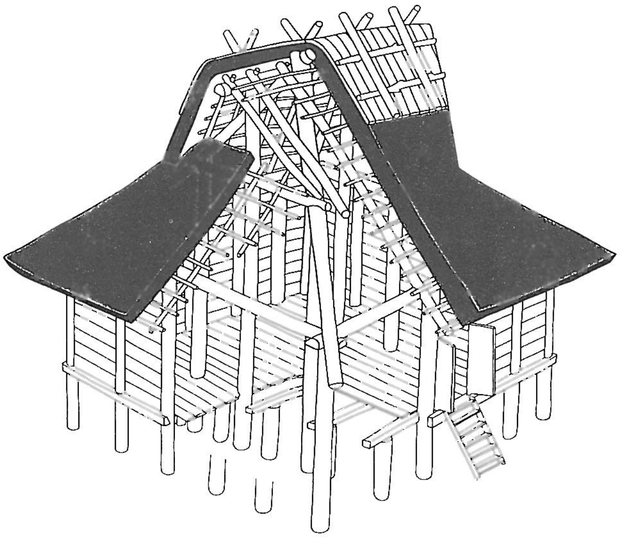

Figure 45.9 Estimated architecture of a wooden building (high-floored storehouse).

45.3.1 ASM: Ancient Scenery Modeller

Limiting our visualisation to such a specialised domain as a village, we can have a clear idea of the expert system needed to support the modelling and related laborious tasks: The Ancient

Artificial Objects

Class	Example
Building	Pit-dwelling, High-floored storehouse, Watchtower, Wooden fence, Gate
Paddy field	(depends on topography)
Tomb mound	Keyhole-shaped, Round, Scallop-shaped, Square-front, square-back
Boat	Canoes, Vessels

Natural Objects

Class	Example
Sky	Clear, Cloudy, Red sunset
Topography	Flatland, Hill, Mountain, River, Water, Coast
Plant	Tree, Grass, Moss
Creature	Bird, Animal, Insect
Weather	Rain, Snow, Fog

Table 45.1 Objects expected to be in the ancient scenery.

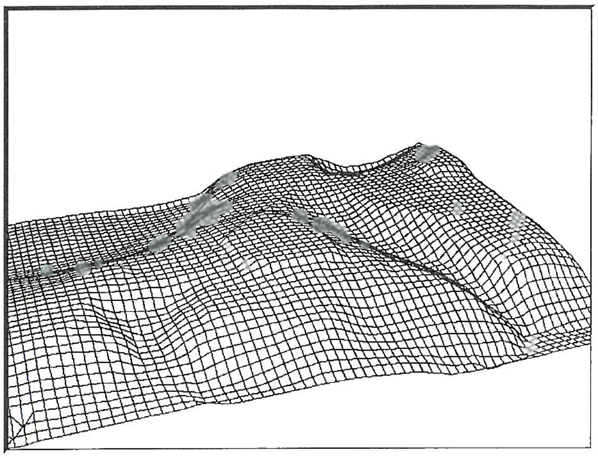

Figure 45.10: Modelled topography of the land where an ancient village was situated.

Scenery Modeller, ASM, has been implemented on a work station to save labour in preliminary tasks before rendering. The database attached to ASM presently stores a small number of made–up models of a high–floored storehouse, a pit–dwelling, a watchtower, a tomb mound, a wooden fence and several types of trees. The modelling procedure using ASM is illustrated in due sequence as follows:

1) *Entry of a reference map.* First, we input topography of the land where an ancient village was situated. Since the topography is usually obtained from a paper–printed contour map, we have to feed it as a reference map to ASM via an image scanner.

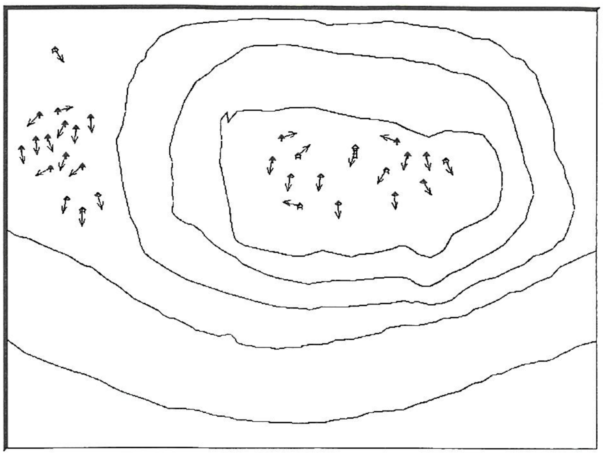

Figure 45.11: Arrangement of objects on a contour map. Each object is indicated by a miniature corresponding to its type. The direction is shown by an arrow.

2) *Definition of contour lines.* On the displayed reference map, we input contour lines in terms of series of points by tracing the real contour lines using a mouse. After this tracing process, ASM keeps all the needed contour lines, not in terms of image data, but spatial data in a three–dimensional world. Then ASM can start surface modelling of the land withtriangle patches. We can confirm the result of the surface modelling by wire frame representation (See Figure 45.10).
3) *Design of a village and surroundings.* Here, selecting objects from the database, we put them on the displayed contour map using a mouse. The objects we can handle are those stored in the database only. Thus we have to specify on the map where to put which objects from the database. Each kind of object placed on the map is indicated by an individual symbol distinguished from others. For example, an arrangement of ancient buildings and other objects is presented in Figure 45.11: Each symbol shows a kind of tree or building with a specified direction. In addition, we have to consider the distant surroundings including mountains, forests and the sky. ASM only defines a very big cylinder surrounding the village as shown in Figure 45.12. The distant surroundings are to be described by texture mapping included in the rendering process: the inner surface of the cylinder is textured using photographic images of real scenery.
4) *Positioning.* After arranging all the needed objects on the map, we have to determine the viewing position where the camera is to be set up. This operation can be carried out using the

keyboard and a mouse. The wire frame representation helps to examine whether the given viewing position is suitable (See Figure 45.13).

45.3.2 Rendering

When all the above is finished, we can start rendering. Our rendering programme has originally been developed on the basis of the ray tracing algorithm. As previously mentioned, rendering time mainly depends on the computer power: For ancient scenery including a village, it takes about five hours (CPU) to generate a picture of 400 by 400 pixels using a 40 MIPS work station and our rendering programme. Figure 45.14 shows an example.

The ray tracing algorithm theoretically provides more realistic pictures than others, but it takes very much rendering time. In our visualisation of ancient scenery, a simple dodge to save time has been introduced: Reduction of the number of primitives contained in a model makes a clear contribution to the saving of memory space and rendering time. For example, our standard model of the tree contains about 500 leaves as primitives defined by triangle planes. When this model was employed for all trees to be arranged in the ancient village, very much memory space would be required, causing long rendering times. One way to avoid this problem is to employ abbreviated models for the trees at places distant from the view point. In fact, no one can distinguish the four distant trees, in Figure 45.15a, generated from differently abbreviated models. When the trees are close to the view point, abbreviation can clearly be recognised as seen in Figure 45.15b. For each object arranged on the map in the design process, ASM automatically selects either of the standard or abbreviated models according to the distance from the view point. This scheme obviously acts well to save time. In theory, there are other technical ways available for saving memory space and rendering time, each being a "cheap" trick that provides no drastic change. Yet, the present technical situation appears to be so premature that we have to make compromises between computing power and reality of generated pictures.

Computing power is also closely related to making realistic animations. Normally, thirty pictures (frames) are presented during one second in an animation. In 1991, we made a thirty second animation, visualising the famous Yayoi site "Yoshinogari" in Kyushu Island. In this project, thirty frames for one second were given by repeating twice each of fifteen pictures. In total, we

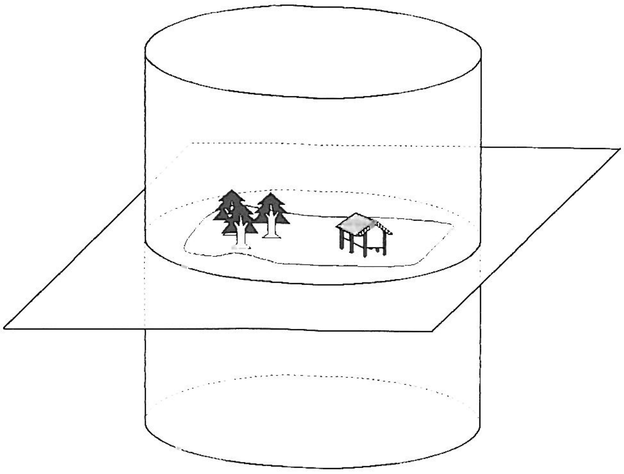

Figure 45.12: Cylindrical surface to be textured.

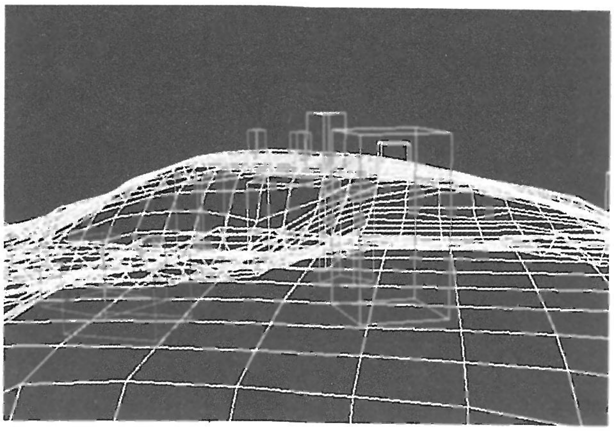

Figure 45.13 Wire frame representation of the scenery given by a viewing position. Coloured parallel lines show the extents of objects.

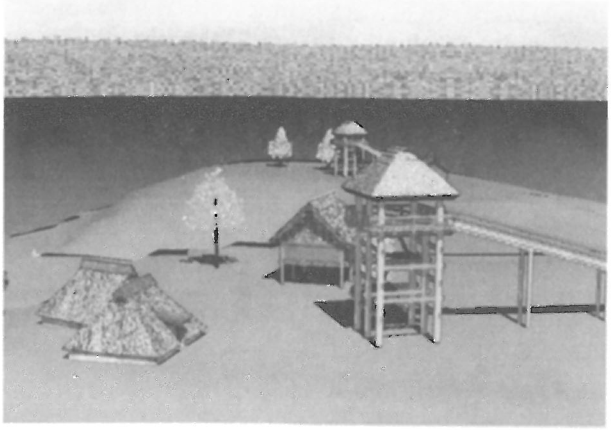

Figure 45.14: Visualised ancient scenery corresponding to Figure 45.13.

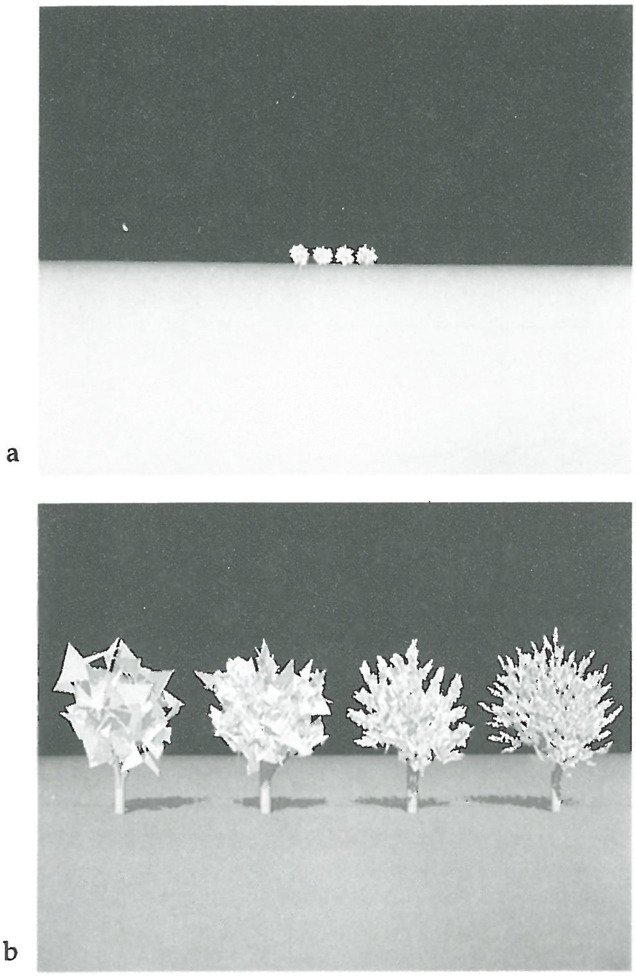

Figure 45.15: Abbreviated tree models. a is a picture of distant trees and b that of close trees.

had to generate 450 pictures by rendering. All things were not always going well. The 450 pictures were obtained through a long process of "trials and errors". It took ten students about forty days using five work stations. Figure 45.16 shows one of the 450 pictures.

As previously mentioned, texture mapping has been included in the rendering procedure. All objects except trees have been textured viaphotographic images; e.g., roofs and walls of buildings and distant surroundings.

45.4 CONCLUSION

In this paper, reconstruction of ancient monuments has been discussed in the light of computer-based visualisation. The technical situation is still so premature that we have to compromise over many matters to visualise lost monuments as realistic pictures. Among them, it is a serious problem that computer-based visualisation needs much human labour. We have no general solution for saving labour during the data handling associated with visualisation. One practical solution appears to be given by building expert systems acting in specialised domains. ESRAT and ASM, presented in this paper, can be regarded as elementary steps towards such a solution.

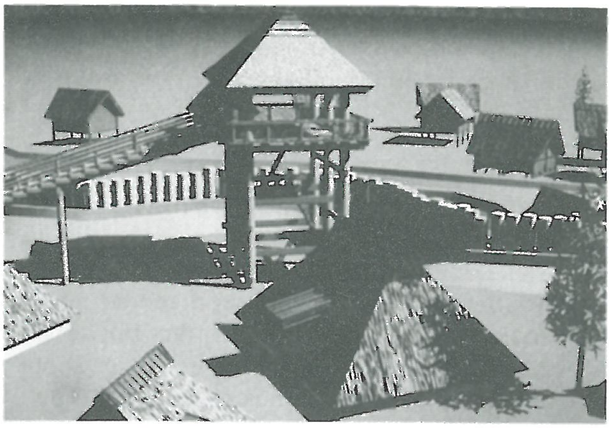

Figure 45.16: Visualised "Yoshinogari Site" in Kyushu Island.

Visualisation will play an important role in changing the archaeological world: Museum, education, publishing and research will be changed corresponding to the information age. The change will, however, grow not dramatically but gradually. Many monuments will be reconstructed, one by one, through each tunnel of trial and error. It looks inevitable that we have to tackle our problems one by one to reach the final goal where we will be able to visualise easily any thing at any time and any place.

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