Modelling the Garden of Perfect Brightness

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Abstract: The *Yuan Ming Yuan*, the Garden of Perfect Brightness, was the culmination of the art of Chinese Imperial gardens. Covering 350 hectares (875 acres) northwest of Beijing, it included 140 distinct sites, 2000 structures, thousands of pieces of furniture and precious objects, countless plants. It was almost totally destroyed in 1860 at the end of the second Opium War by English and French troops in one of the worst acts of cultural vandalism in recorded history.

Rebuilding it has proven impossible, but now computer technology, based on 130 years of scholarly documentation makes it possible to build an accurate and detailed model, and will allow us to experience at least virtually the beauty and grandeur that was the Yuan Ming Yuan.

This paper describes a project to build such a model, and details the main challenges and difficulties encountered. While commercially available graphics workstations and modelling software can take us most of the way in this task, they fall short with the modelling of natural phenomena such as plants, rocks and bodies of water. In addition the sheer size of the resulting database pushes rendering engines past their limits.

Keywords: Yuan Ming Garden, Chinese culture, architecture, landscape, natural phenomena.

1. Introduction

In traditional Chinese culture, gardens were designed to be a totally integrated expression of nature and culture seen through each other's perspective. As such they included and harmonized hills, bodies of waters, trees, plants, rocks, buildings. All these components were staged to be seen individually and together in many layers of discovery and wonderments. As in poetry and painting the goal of of the art was to elicit both the surprise of novelty and the pleasure of recognition. The Garden of Perfect Brightness, the Yuan Ming Yuan, represented the masterpiece of centuries of practice of this art. Located northwest of Beijing, in the middle of the "sea of gardens" near the Summer Palace, it was comprised of three individual gardens (the Yuan Ming Yuan proper, the Chang Chun Yuan and the Yi Chun Yuan) covering 350 hectares. It was built during the Qing dynasty, over a period of roughly 150 years, starting with emperor Kang Xi. In 1960, at the end of the second Opium War (the so-called Arrow War), British and French troops led by the Eighth Earl of Elgin pillaged and destroyed the garden, along with adjoining gardens on Fragrant Hills and Jade Spring. The fire in Yuan Ming lasted for three days and three nights. Ironically the main identifiable remaining ruins were from Western style buildings made out of stones, which actually constituted only about 5% of the total. Even the complete destruction and obliteration of Versailles, gardens, buildings, furniture, all artifacts, would pale compared to this incredible act of vandalism.

The essential structure of the garden was as about 140 different *sites*. Each site consists of buildings (a total of about 200 individual structures), landscaping, from the original terrain as well as artificial hills, valleys, streams, waterfalls, ponds, and even "seas" (the Sea of Fortune was half a mile to its side), trees, flowers, water plants, and even animals were integrated into each site. All the sites together created a reduced version of a whole ideal country, with indeed sites or elements of sites designed to evoke famous landscapes of China or other celebrated gardens (see general map as Figure 1). Every component and every detail was important, the decoration and material was rare and expensive, and the interiors were lavishly furnished and decorated with the best paintings, books, jewelry, jades that could be found anywhere. Yuan Ming Yuan was in fact the largest and richest art museum China ever had.

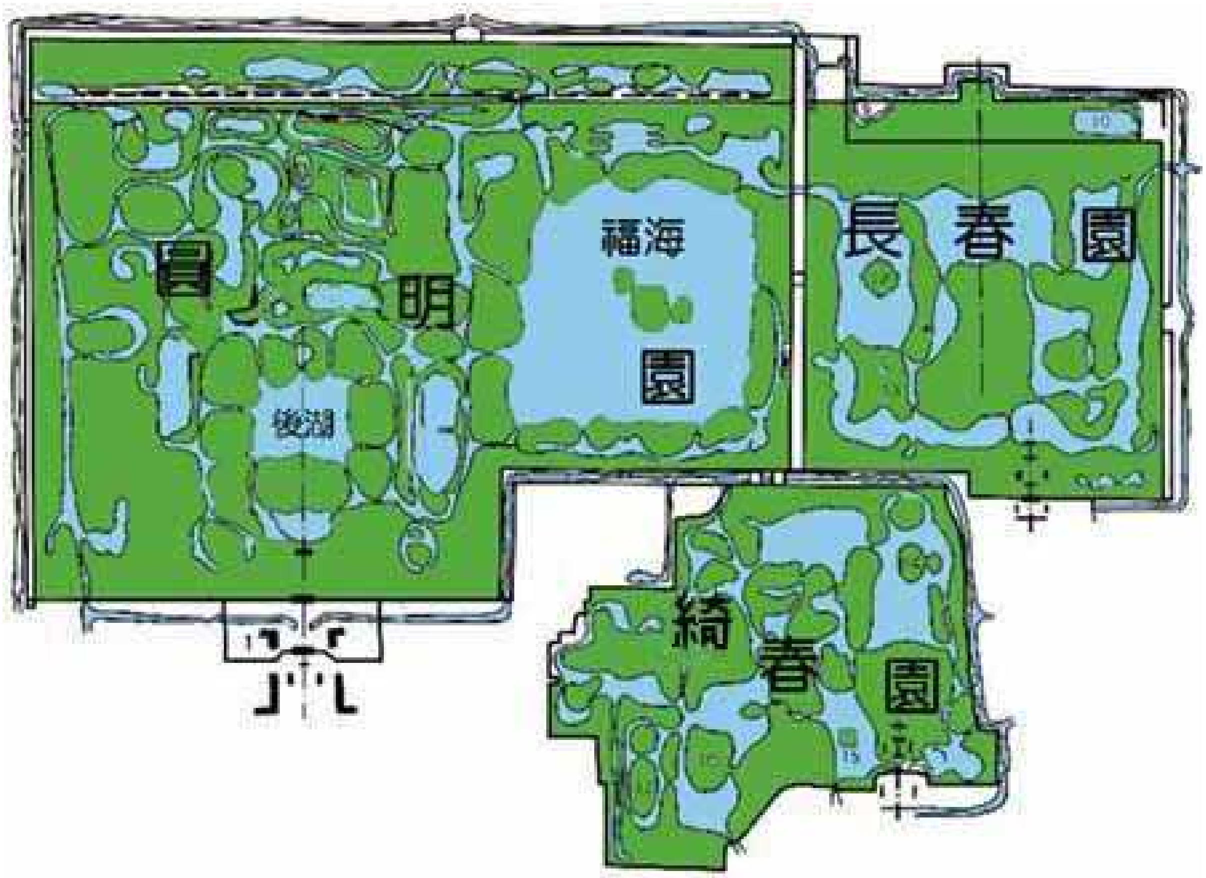

Figure 1. General map of the Yuan Ming gardens

2. The Project and its Goals

Simply put the project is to build as complete and as accurate a computer database as possible to "reconstruct" virtually the Yuan Ming Yuan. It was started three years ago (1993) at the initiative of Lifeng Wang, with the support originally of GraFiC and Imager, two computer graphics groups in the Department of Computer Science at the University of British Columbia, and is now undertaken by Xing Xing, an independent company founded for this purpose.

The intended uses of the models are multiple, and sometimes contradictory in their goals. The main goal is to serve as a permanent reference document for scholars, artists and students who want to obtain an accurate view of what the garden was. In that sense the models should include everything that is known about the landscape, buildings and interiors of buildings, and the size of the database and the rendering times are not relevant factors. A second goal is to provide a database for non-real time applications such as sets and backgrounds for movies, television shows or in general applications that can use off-line animation and rendering. A third goal is to serve as a database for interactive or near interactive exploration of the garden. In this case the size and the rendering time become important factors. In many applications, however, animations can be precomputed, and for real-time applications simplified models can be extracted automatically or semi-automatically from the more complex database, as for instance, in Hoppe's work [7]. Such applications include interactive CD-ROMs and educational games. The last category of uses is virtual reality, where it is imperative to animate in real-time. While there are no commercially available VR system that can handle the models necessary for even a modest amount of details, research system are close to the necessary requirements [3].

3. The Sources

A large amount of research material is available today after decades of dedicated work by scholars in China and the rest of the world. A survey of the site combined with old blueprints resulted in a relatively accurate full map of the garden [8]. Many researchers focussed more into the specifics of each garden site, for example what title board was hanging in a specific building, what words used for the specific couplets inscribed in front, and what type of plants were featured in which site [18].

The authentic original look of the garden was derived from the numerous paintings done before the garden was destroyed and still extant. The most famous ones are the *Forty Views* paintings currently located in the Bibliothèque Nationale in Paris, France [17]. Besides those paintings, which show sites from an overview perspective, there are other existing paintings of the garden in close-up, with emperors and their wives as main characters in the scenes [19]. These paintings give a good idea of the original beauty of the Yuan Ming, and we have followed the gardening styles shown in the to model details of the garden.

For many aspects of the landscaping, architecture, and especially for the details of interior furnishing, the information has been lost. For example we do not know exactly which color and which patterns have been used to paint the beams of a specific building. However the general style of this type of decoration has been investigated and documented [1], and we followed carefully the general rules to re-construct the architecture. The architectural dimensions have been calculated according to the strict rules of Chinese classical architecture based on the information available [14]. We also used the many existing Chinese gardens as reference, and base the reconstruction on them as well as on the material available in the literature.

4. The Basic Tools

The basic modelling tool used for this project are the Alias modeller (currently Alias Studio 7.5). Alias Studio is a very good modelling tool for intricate and organic looking Chinese classical architecture. Its full suite of tools for texture mapping and rendering are very important for the imagery we generate. The results so far are testimony to its generality and power, and in general of the degree of sophistication and ease of use reached by today's commercial modellers.

The main drawback of this modeller is its relative inefficiency in handling large databases, and its limited ability to model natural phenomena, in particular plants. We will describe in the following section some of the steps taken to address these problems. Because now Alias Studio (as well as other commercial packages) has good plug-in structures, we can consider seriously plug-ins-gins for specific modelling tasks. One example is to write a tool to model Chinese classical architecture procedurally according to the rule specification. That would relate to earlier work in Western architecture, in particular at Harvard [6][2].

The hardware used were originally IBM/6000 machines running Alias 3.2. For reasons having to do with slow updating of the hardware and weak support of IBM machines by Alias (now paradoxically improving) we have largely switched to SGI machines running the current version of Alias studio. We routinely use 5 workstations in this project, from Indys to IBM 6000/560, but with the machines from the Imager lab an undergraduate teaching lab in the UBC Computer Science Department we can access up to 25 workstations in a rendering emergency.

5. State of the Model

So far, we have created a detailed, accurate and large database of models, images and animations. The models are mostly NURBS based spline models, with some polygonal models for plants and stones. All the models are stored in DXF file format. There are currently about 800 models in the database, occupying 2 GB of disk space. Among them, there are about 200 architecture models, 300 furniture and object models, plus models for animals, trees, flowers, rocks, etc. A standard architectural model will have more than 100 spline patches, which convert to more than 500,000 polygons when rendering.

Figure 2 shows an overview of one complete site, the *Scholar's Delight* (Lian Xi Le Chu). Figure 3 gives an example of a building. Is has been rendered with approximately 1 million polygons. Figures 4 and 5 show an interior scene and a piece of furniture. In terms of the ultimate goal of reconstructing the entire Yuan Ming Yuan, approximately 10% has been done. This indicates that the total database will have about 20 GB of data, exceeding a 32 bit address space.

Even considering that we are far along our learning curve, and that with the help of new and better tools our modelling speed will only increase, that means at least 5 years are necessary to restore the rest of the more than 100 garden sites.

Figure 2. Overview of the Scholar's Delight

Figure 3. A pavilion

Figure 4. Interior scene

Figure 5. A bed.

6. The Modelling Challenges

As difficult as it is to model buildings and furniture, the modelling of the natural elements of the garden is even more challenging, because they have all the complexity of nature, but at the same time they are highly controlled in shape and look, either by careful selection or by direct intervention.

6.1. Plants

Plants in Chinese gardens are not limited to the shrubs and flowers, but as with the rest the plants represent a microcosm of the vegetal world. Among the representatives are bamboo, peony (tree and herbaceous), chrysanthemum, lotus, camelia, rhododendron, water-lily, orchid, elm, ash tree, catalpa, gingko, willow, dogwood. Hemp was a favourite ground cover. Botanical accuracy is of course necessary, and many of the trunks, leaves, flowers have indeed very complex shapes. We estimate that there are at least 500 types of plants in the garden, some rare, some even artificial.

With care and time, but mainly for rendering efficiency and speed, many plants have been created with Alias studio, either directly or with particle system. These plants are ideal for distant views.

P. Prusinkiewicz and his collaborators [16] have built many tools, mostly based on L-systems specifically to model plants, and has been very generous in providing his software and training to use it for our project. Its modelling power is very good, but its main drawback is the large database it creates when converted to DXF format. Also its descriptive, textual approach is relatively difficult for most artists, which has inhibited our full use of it. The former problem can be addressed by developing the L_system based modeller as an Alias plug-in, but the other problem remains.

For plants modelled specifically for closeup rendering, a specialized interactive plant modeling package [11] is being used (please refer image wang.plants.tif.gz, printed version too poor).

6.2. Stones

Stones in Chinese gardens are often set as miniature mountains, and are expected to be as varied, interesting and complex as the full-sized mountains. Natural "found" stones have always been highly praised and sought by collectors in China, and gardens always included examples of these. Stones found in lakes and made of soft material with large holes eroded away were especially prized, and stones from lake Tai, in particular, were extremely famous. Modelling this kind of stone is a challenge, because we are trying to model a specific appearance, and often a specific stone, but at the same time we want to achieve a natural look.

We therefore developed our own models for this kind of ornamental stones [4]. The overall shape of the stone is modelled using any surface modelling tool (polygonal meshes, parametric surfaces, spheres, etc.). This shape is then scan-converted into a 3D grid. The size of this grid is chosen as a function of the level of details to be achieved for the resulting stone. Then the holes are modelled by spheres (actually they can be modelled by any volume that can be scan-converted, but spheres are sufficient in general). These spheres are subtracted from the overall shape by a *constructive solid geometry* operation. The result is now an object defined in a volumetric grid. To produce the object as polygons to be imported into Alias or any other rendering system, we use the *marching cube* algorithm [12].

An example of the result, compared to a picture of a real stone we used for the overall shape is given in Figure 6.

Figure 6. Real ornamental stone and model

In the example given the model has about 3000 triangles, and has topological holes. Again a coarser or finer version of the same rock can be output with a coarser or finer grid. When rendering we have applied a fractal 3D texture to the surface to make it appear more realistic. Different types of rocks can be obtained by changing the shape and distribution of the holes in the material.

6.3. Water

From the Sea of Fortune to the hundreds of ponds, streams and waterfalls, water covers more than half of the garden. Water plays a static role (as a reflecting surface) as well as a dynamic role, in streams, currents and falls. The main modelling challenge is therefore to include the dynamics of water. For example, when a boat runs through the water, or the water around a boat (there are many stone or otherwise motionless boats in the garden) it is extremely difficult to create the waves and splashes by hand. When a fish jumps, the splash is also difficult to create. Figure 7 shows fishes in a pond.

Figure 7. Surface of a pond

Even though they are good models for waves [5] wakes [10] and moving water in general [13][9][15], we have not yet included them in the Yuan Ming model.

7. The Rendering Challenges

Rendering time, especially when animations are to be produced, is real bottleneck for this project, considering our limited computational resources. This is partially because Alias' renderer is not very efficient, partially because our database is huge and the quality we require is high. On average, one good quality image at NTSC resolution (645x486) takes a 200 MHz SGI with a 180 MB RAM 20-30 minutes to raycast. If we use the raytracer, the rendering time goes well into the hour range.

One way to reduce dramatically the rendering time is to edit our models for each scene; however that will be very time consuming, this time in human terms.

We have used extensively Wavefront (now Alias/Wavefront) *Composer* to achieve manageable rendering times. We render different components of the scene separately and compose them together. Moreover the Composer can be used to filter down images for better quality, and to process the images to give them an unified look. Some scenes we rendered were composed of up to 24 different layers of compositing.

Water reflection present an other rendering challenge. Alias' raytracer is unrealisticly slow for this purpose so we have written our own software to create fake reflection from water surfaces. This software needs to be improved and incorporated into Alias Studio or the Composer to work more efficiency.

We of course use texture mapping extensively to reduce the "geometric count". One custom trick we developed is to replace leaves of plants at a distance by spheres with 3D textures.

The real-time rendering of these models is not expected to be feasible soon. We are planning to create a VRML based virtual on-line world using Java, but this currently takes too long to render even after omitting 90% of the textures.

8. Conclusion

In many ways modelling the Yuan Ming Garden is modelling the world, and the challenges we met are the challenges every modelling project has to face in some form. We have the distinct advantage to know that if we are faithful to the subject we will have a culturally, esthetically and historically significant result.

That we have gone so far is partly to be credited to the quality of the current commercial modelling and rendering tools, but we have along the way identified some of the difficulties especially when modelling natural phenomena if accuracy is necessary.

The original goals are all reachable. The models have scientific value, they can and will be used in interactive CD-ROMs, and at least at the research level some of our models are being used in Virtual Reality (by F. Brooks and his collaborators at the University of North Carolina).

What we have accomplished so far can be seen in our web pages at `http://www.cs.ubc.ca/nest/garden` with more background on the Yuan Ming Yuan and many images. We also have produced several animated sequences gathered in a ten minute video.

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