THREE-DIMENSIONAL PLANT MODELING AND SIMULATION:
HOW FAR DOES RECENT COMPUTER TECHNOLOGY EXPAND
TO ASSIST THE LANDSCAPE ARCHITECTURE PRACTICE

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GRADUATE RESEARCH PROJECT

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DECLARATION

"I hereby declare that this thesis entitled **Three-Dimensional Plant Modeling and Simulation: How Far Does Recent Computer Techn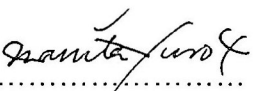ology Expand to Assist the Landscape Architecture Practice** is the result of my own research except as cited in the references."

Signature :

Author : Hanita bt. Yusof

Date : 2nd January 2008

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بِسْمِ اللهِ الرَّحْمٰنِ الرَّحِيْمِ

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1.0 INTRODUCTION

There are some contradict perceptions on the issue of advance digital application related to landscape architecture field. Either there is no advance digital application being invented for landscape architectural design purposes or another perception that there are probably few applications related to landscape architecture field but not being utilized by landscape practitioners in landscape design practice. This particular research topic on 'three-dimensional plant modeling and simulation: how far does recent computer technology expand to assist the landscape architecture practice' will answer the perceptions based on literature studies done by researchers all over the world as well as the recent information by the vendors which both related to this research topic will finally reveal the actual situation.

1.1 Landscape Architecture and Role of Landscape Architect and Designer

Landscape architecture is a field that involve with nature such as flora and fauna, landform and ecology and it has very close connection to architecture field where a building project might have landscaping work within the same project. Landscape design includes both softscapes such as plants and water bodies and also hardscapes such as pavement and pergolas. Landscape studies basically involves planting design, spatial arrangement, ecology, ecosystem, construction as well as master planning involving location, sizing, topography that can be an advantage in designing and planning a site for a stormwater management. It's also important to consider on landuse, zoning, circulation, utility and community of the surrounding. Site should be analyzed through site inventory and mapped with a different suitability assessment layer for each relevant factor. It has the quite similar work process with architect basically from site inventory, analysis and design process up till the outcome of few design alternatives through several presentations before final proposal. Thus, the role and task of landscape architect or designer is more or less equivalent to architect especially on its

sequence of design process where it involves design, crit, presentation, amendments, documentations and in that case it need to be at par with the architects when it comes to computer application. Obviously, all these process will be much more faster, easier and accurate if it can be done with the help of computer technology.

1.2 Significance of Computer Based Technology in Landscape Architecture

Landscape architecture often involves with large scale of projects having huge site like parks whether it is open public park or even theme park, urban greenbelt or green corridors, campus and site design for institutions or housing areas, waterfornt or promenade, botanical gardens, arboretums, and nature preserves, recreation facilities like golf courses, amusement parks and even sports facilities. This is another good reason why it really needs a good computer application to assist the design process. Landscape design have so many element such as landform, plant materials, buildings, hardscape structure, pavement to be utilized in the landscape design that will be much more inspired with the help of the advance computer application such as the object information modeling from conceptualizing stage and the making and analyzing their design.

1.3 Integration of Conventional and Advance Computing in Current Landscape Architecture Work Process

Currently, the most popular way of doing the landscape design is the combination of both manual and computing. Some of the landscape architects have played a major part in the development of GIS and, with a CAD built-on, it is likely to become the most widely used landscape graphic software. McHarg's use of overlays in Design with Nature is accorded an important place in histories of GIS. When it comes to design process, most landscape architects still prefer to manually hand sketch his idea in a peace

of paper and transfer it to CAD software for two-dimensional plan, elevations and sections. Most of them still draw the three-dimensional drawings manually saying that the plants will look more natural in freehand unlike building. Probably the lack of knowledge on the recent advances software provided that has a lot of two and even three dimensional plant software available in the market.

Nevertheless, no doubt that many landscape architects now have used digital plant library in computer database to do plant selections but it only limited to still images not object modeling that can work for simulation and animation. As for presentation, the still drawings done in two-dimensional CAD will then be rendered and coloured either manually or using computer. For photo-editing work landscape architects will make use of image-editing software (eg Photoshop and Photopaint). These programs encourage exploration of photomontage as a conceptual and graphic tool. Having said that, there are a lot more opportunities to integrate even more computer technology available for landscape architecture field created in the market. However, there is no effort of taking the advantage of manipulating every advance computer application emerge recently and make full use of it in design process as early as possible. Danahy (2001) believed that the role of a computer-aided-design system should be to assist the designer in developing and managing the information used in a complex environment design problem and to allow for accurate rendering of all design alternatives considered. Visual information generated by the computer will definitely influence on decision-making when being used as early as possible in the design process. Sad but true, most of these advanced visualizations are developed only after the real work is completed, and often only to 'sell' the resulting proposals for marketing purposes.

1.4   Issues and Problem Statement

Unfortunately, unlike the architects, those landscape architects are still few steps behind when it comes to computer technology application and

utilization within their design process. Almost all landscape design practitioners are still comfortable and satisfy using the manual approach in handling the design exploration and presentation techniques. These won't allow the landscape design professions to be able to expand to a collaborative design strategy. Within contemporary digital environments, there are increasing opportunities to explore, analyze and evaluate design proposals which integrate both architectural and landscape aspects. The innovation of integrated design solutions exploring buildings and their surrounding context is now possible through the design development of shared three dimensional and even four dimensional virtual environments, in which buildings no longer float in space.

There are presently still too many landscape architecture practitioners as well as in academic departments where computer based design activity is seen as an isolated from the whole design process where it is only be used more for two dimensional instead of three dimensional tasks. With recent technological developments in computing, there is a huge opportunity for a range of landscape element and component template and rich information modeling to be explored. An increasing amount of online data is large and available compared to years before. A rapidly expanding area related to landscape architecture is Geographic Information Systems (GIS). Another expanding area is the use of object-oriented technology in CAD.

Nevertheless, for this particular research paper, I will explore on plant as the main object for the information modeling and the possibilities to be applied in landscape architecture design practice towards better possibilities of having an effective design and time consuming results. Eventhough plant is obviously one of the main elements in landscape design, there is still conventional method in addressing the plant in the design process.

The main and leading character of visual landscape simulation are plants, the aspect that has traditionally proved to be one of the greatest challenges for landscape representations. Paar (2006) also believed that as most landscapes are covered with vegetation, the representation of plants and

vegetation is a prerequisite for realistic visual simulations of landscape sceneries. Furthermore, plant itself is the primary character in visual landscape simulation. This clearly stated that a digital application related to plant is vital.

The absence of plant information modeling software is a huge disappointment since choosing and analyzing plant is important. Without using the correct plant selection in addition of having a good landscape design and planning, the level of success would not be so great. As Preece (1991, p.256) says that trees are joy, but the wrong tree in the wrong place is nuisance. Due to that reason, this research will mainly be focusing on the plant material particularly in three dimensional plant modeling and simulation where this is main issue lacking in the landscape design application.

1.5   The Capability of the Latest Advance Computer Application Related to Landscape Architecture Field

Significant increases in the performance of computers are now making it possible to move on from symbolic representations towards more contextual and meaningful representations. For example, the application of realistic materials textures to CAD-generated building models can then be linked to energy calculations using the chosen materials. It is now possible for a tree to look like a tree, to have leaves and even to be botanically identifiable. It will be good to have more realistic effect like having parametric value for instance the density of leaves or length of branches and are capable of surprisingly informative and realistic simulation of each landscape elements. In other words it should be information rich modeling approach. In the effort to model and visualize landscapes, we need to seek a balance between 'look like' and 'acts like'. It is easy to have the plant that 'look like' plant but it is difficult to achieve plant that 'act like' or 'behave like' plant. The building and landscape can be rendered from a common database of digital samples taken from the real world. The complete model may be viewed in a more meaningful way either through still images or animation, or better still,

through a total simulation of the lifecycle of the design proposal. The model may also be used to explore environmental/energy considerations and changes in the balance between the building and its context most immediately through the growth simulation of vegetation but also as part of a larger planning model. The latest one can predict what it may look like in future time for example the effect of the plant growth after five or ten years ahead. These will help to predict how the shading or visual created by plants will affect the building or even the landscape sceneries after few years.

Surprisingly, there are ample of interactive modeling of plant application nowadays. Observing the current landscape practice and educational exposures in academic level, one would think that there is no advance plant modeling software at all available but amazingly it does. In this digital modeling field a lot of method and system created to model a plant such as Texture Mapping, Fractal and Lindenmayer system or known as L-system used in the earlier stage up till recent ones such as LIGNUM, Canonical GUI system and Lenne´3D system where these latest systems are an improvised version targeted at previous limitation and weakness of earlier invention. Integration of more than one approach will give much better result. For instance the combination of L-system with LIGNUM or canonical modeling with L-system. More software applications which offer plant modeler application emerged based on some of this system such as TREESTORM by Onyx TreeMaker, EASYnat by Bionatics, Lenné3D, SpeedTree, TreeMagik, PlantStudio, Plant-Life and XFrog. All these would be explained further in the following topics.

Plants not only complex in their basic structure, they also represent another dimension altogether in the landscape which is dynamics and change over time. Plants grow on an annual cycle, sometimes changing their form dramatically, and not just by simple scaling; many change character on a seasonal cycle, shedding, re-growing and re-colouring their foliage; and often plants move and change with daily solar cycle as well as shake and sway with the wind. Ervin (2001) also believed that modeling a tree's basic geometry is a daunting challenge; making it grow and change overtime or

blow in the wind (digitally) is even more so. Some software has begun to approach these challenge, adding to fractal plant-form generation, plant growth or wind motion, and these are already essential utilities for digital landscape modelers such as those mentioned before.

2.0   PLANT DATABASE

2.1   Intelligent Sources of Digital Plant Database

Plant or may also be termed as vegetation is consists in various categories. In landscape architecture field plants are categorized into trees, shrubs, palms, bamboos, vines (climbers and creepers), groundcovers and also aquatic plant. Those categorization are sort based on their physical characteristic. In landscape practice, landscape architect or designer will need to choose an appropriate plant based on the design concept and theme, design principles and most importantly objectives because different plant serves different landscape function. Plants are selected based on its characteristic and landscape function, suitability as well as aesthetic. Traditionally, all these information are gathered in books with all the images. Then there is electronic library or e-library where it is a digital library consists of plants species with every botanical information including still images.

Information of plants characteristics such as shape and profile, size of maturity, nature of foliage, special features of value, rate and pattern of growth, strength of wood, flowering habit (can see what it looks like in summer, autumn, winter and spring effect whether its evergreen or deciduous) are included in the database.

Recently, some of these plant databases have been equipped with three-dimensional images instead of two-dimensional images of plant. AMAP stands for Atelier de Modelisation de Architecture de Plants is a commercial library of plants is one of the pioneer in virtual nursery field. Many researches have been using AMAP plant database where they used plant images

generated by AMAP and simulated various landscapes using the AMAP system.

Honjo and Lim (2003) experimented a research digital plant modeling to express plant by texture mapping also using computer graphics images of plants made by AMAP where he claimed that AMAP is a high-performance visualization system for landscape planning developed by Center Internationale Recherche Agricultural Development (CIRAD) that produces high precision three-dimensional plant shapes. AMAP is one of the outputs of the study of plants. AMAP generates very botanically realistic three-dimensional computer graphics where images of several growth stages can be easily made and are used as a texture. This three-dimensional plants made by computer graphics by AMAP or other similar techniques consist of polygons. Branches, twigs, flowers and leaves are all described by sets of polygons. The number of the polygons varies between thousands to millions. Such a polygon model is suitable for photo realistic expression of the plants but needs large amount of time for the rendering and additionally, walk-through simulation is difficult in VRML. Therefore, this method used only 2D textures and a 2D plant image database was developed. Examples of plant images in the database are shown in Figure 1.
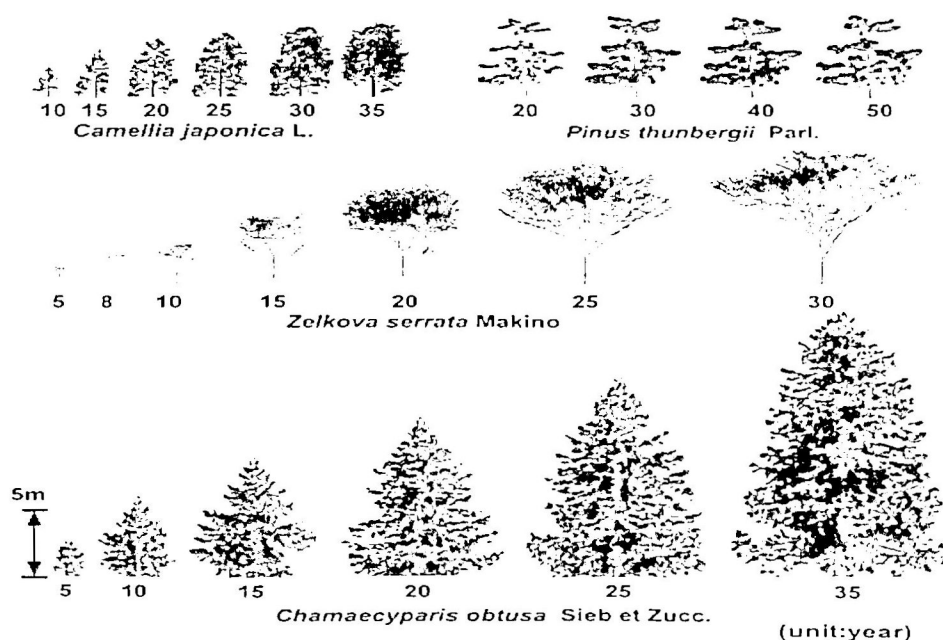

Figure 1: Examples of plant images in the database. *(source: Honjo and Lim, 2001)*

This texture mapping method using the 2D image from AMAP database is one of the earliest method used. To make a fast rendering of plants, the texture of plants which are in a transparent GIF format are mapped on a plane and two planes are crossed to show the plants as shown in Figure 2. This method is very effective for the fast rendering of plants thus make it very popular. There are many methods to model plants. Muhar (2001) claimed that the use of texture mapping in connection with simple 3D-faces is a very popular method of plant visualisation in landscape architecture. Texture mapping implies the projection of raster graphics onto a modelled surface in order to alter the surface characteristics, such as the colour or the transparency. In the case of plant visualisation a photograph of a real tree can be mapped onto a rectangular vertical face (billboard); in the rendering process the areas of the image background are treated as transparent shown in Figure 2 and 3.
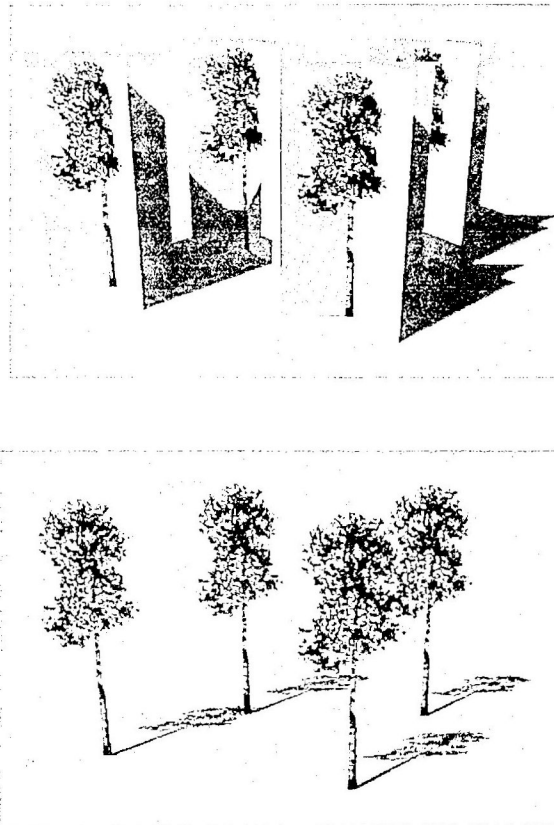
Figure 2: Plant simulation via texture mapping: a tree image is mapped onto a simple rectangle. The background colour of the image is rendered as transparent. One such "billboard" faces the viewer, a second one faces the sun and is only used to cast a correct shadow. *(source: Muhar, 2001)*

Plants consist of a large number of individual elements, however, the configuration of these elements follows relatively simple rules (e.g. the branching pattern within a genus is usually constant). Therefore, plant modeling algorithms have to find ways for a formal mathematical description of the 'genetic construction plan' of a plant.
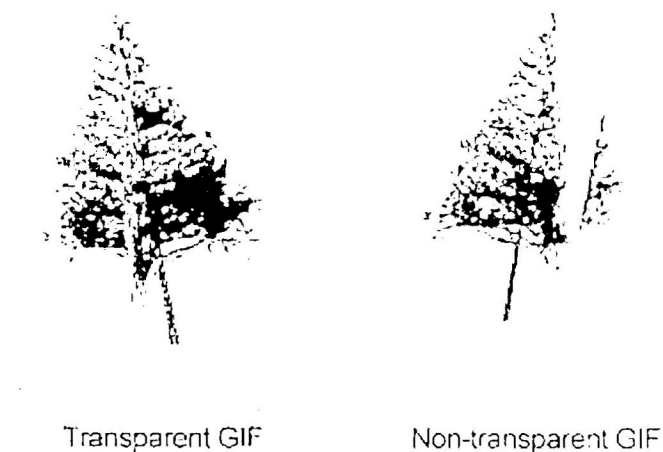

Transparent GIF   Non-transparent GIF

Figure 3: Example of trees images made by two textured planes with transparent GIF and non-transparent GIF. *(source: Honjo and Lim, 2001)*

This texture mapping is a starting point of more inventions of plant modeling and rendering application. Danahy (2001) strongly believed that the breakthrough for three-dimensional landscape simulations came when image-processing techniques were merged with geometric modeling. These techniques, referred to as texture mapping, have constituted a "profound improvement", as they have enhanced image quality and opened the door for real-time rendering of virtual models. In this hybrid approach, much of the explicit, realistic information is sampled from the real world and is not computed (e.g. leaf texture in 3D plant models). Using an expression of a plant's genetic code, AMAP technology constructs virtual models of plants and trees that are botanically coherent. It reproduces an infinite number plant, each unique, true-to-life and simple to generate and animate. For the first time ever, virtual "living" models can simulate with realism the evolution of a project within its space and time.

Another popular method for modeling a plant is L-system. Renton et al. (2005) explained that these L-system models can give a topological, geometrical and graphical representation of the plant. In L-system models the development of a plant's structure is expressed as a changing string of symbols where each symbol represents a plant component such as a leaf, internode or apical bud, with square brackets enclosing lateral structures in Figure 4.

I[L]A   I[L]I[L]A   I[L]I[L]I[L]A

Figure 4: Consecutive stages of development of a plant modeled by a simple L-system with production rule A → I[L]A. The structure is represented by a string of characters that changes over time. I stands for an internode, L represents a leaf and the apical meristem is symbolized by A. *(source: Renton et al., 2005)*

The dynamics of how the string symbols change is controlled by a set of growth or production rules. This resulting dynamic plant structure can then be visualized in realistic or schematic ways, easily related to the appearance and architecture of real plants.

3.0   PLANT MODELING

Vegetation can be modeled either at the level of individual plants or as a terrain texture. The plant modeling method is determined by the objective whether to perceive the plant as in individual or in a whole bunch as in a forest. It is important to determine the scale in order to achieve good level of detail. Muhar (2001) clearly described the difference in scale-dependant visual perception of vegetation where at object scale, a plant is perceived as a complex structure, consisting of a large number of individual objects like leafs, flowers, twigs, trunks, etc. whereas at landscape scale, vegetation is usually perceived as a texture of the terrain; individual plants cannot be

distinguished. In other words saying that plants in the foreground of a scene have to be modeled as three-dimensional objects, while for the background other approaches can be applied, such as texture mapping. However, for landscape architectural design purposes, most plant would be modeled as single / individual instead of forest strand.

3.1 Significance of Plant Modeling Application in Planting Design Process

As practical as it is, planting design is an art. Having determined what functions are necessary to it, the designer's next task is to apply the principles of planting design in artistic composition. Up to this point, only size and general placement have been considered. Now it is time to furnish the design with real forms that can be sensed, felt, and seen.

Planting design process which includes planting design principle, planting design purpose, planting design arrangement and spacing (mass/group) really need such advance application. Planting design purpose would considered on aesthetic value such as flowers and foliage, an abstract value such as lines, shapes, forms, textures, colours and visuals, a functional value such as shade, barrier, hedges and screen. To choose and analyze the impact on this can be assist by advance application.

Plant materials have many sensory qualities. We can see their characteristic in various forms, textures, and colors. We can feel their textures. We can smell their fragrances. We can even taste their foliage, blooms, and fruit. But in order to create a pleasing landscape design, we must coordinate the functional uses of plants with our sensory perceptions. We can see plants in various forms or shapes, colours and textures. Although the form of each plant is unique, there are general classifications of forms. Trees can be round, columnar, conical, oval, spreading, weeping/willowing, vase-shaped or pyramidal which can be seen in Figure 5. The outline of a tree depends on its branching pattern. Narrow and crotch angles at the point where lateral