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Digital Media Applications to Landscape Design: **Using Procedural 3D Modeling Software and Machinima Software for the Development of Landscape Design Graphics**

By Alejandra Feliciano

Iowa State University
College of Agriculture and Life Sciences
Department of Horticulture

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Landscape design graphics are instrumental in both improving the quality of work produced during design development and in improving communication between clients and design professionals. Machinima and procedural 3D modeling software such as Vue, The Plant Factory, and LumenRT offer great potential in improving landscape design graphics.

MY COMPUTER IS CRASHING: THE PERENNIAL CHALLENGE OF CGI IN LANDSCAPE GRAPHICS

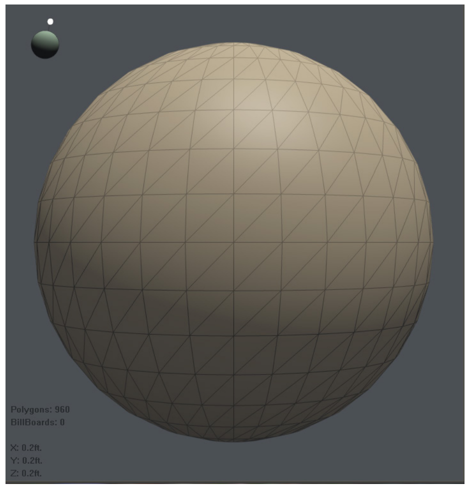


Figure 01. Example of a 3D model. The basic unit of all 3D modeled objects is called a polygon. Polygons are triangular, flat surfaces. Together, these surfaces form a polygon mesh. In this example, a sphere is generated from a polygon mesh containing 960 polygons. As the number of polygons increase, so does the resolution of the mesh.

Figure 02. Example of a 3D model rendered with a reflective material. In this case, a photo-realistic appearance of a reflective material simulates the level of diffusion on the material's microscopic surface. An object with a rough surface will cause part of the light rays to bounce off the small cracks and crevices on the surface. This traps part of the light, so that only a fraction of the rays may reflect off the surface, resulting in a dull appearance. Conversely, an object with a very smooth surface will reflect most light rays off its surface, resulting in a shiny appearance.

Creating a fully immersive digital landscape scene has always been a challenge. It slows most 3D modeling software to a frustrating crawl. The challenges come in many forms: terrains, adjacent architecture, outdoor amenities, and of course—plant material. Modeling the necessary geometry to convey a design used to be close to impossible—imagine modeling trees with thousands of leaves, placed in large quantities, along with a myriad of shrubs, grasses, and forbs. To top it off, we often work at large scales, with projects often spanning multiple neighborhood blocks. But to truly understand why these tasks make us so familiar with a recurring blue screen we need an understanding of how these images are put together.

The process of producing computer-generated imagery (CGI) can be broken down into three main tasks: 3D modeling, 3D rendering, and layout and animation. Three-dimensional (3D) modeling is the process in which a three-dimensional surface is represented graphically through the use of dedicated 3D modeling software. Although objects are defined in three dimensions, the final output is typically displayed in two-dimensional outputs, such as computer screens, projection screens, or television screens. The process of displaying 3D models as two-dimensional (2D) images is commonly known as 3D rendering.

Once the geometry has been modeled, materials are applied to provide a desired appearance (see *Figure 01* and *Figure 02*). Rendering can involve simulations of light reflecting off the surface of objects in a scene based on an object's material properties. Materials can be shiny, dull, transparent, opaque, bumpy, smooth, an so on. Light simulations often involve an understanding of optics in order to resolve the path a ray of light might take through or off of a given object, depending on the surface material applied.

The final task is layout and animation. Once the object geometry has been modeled and materials have been applied, the object can be placed in a "scene" and assigned an animation path, if desired. On the example shown in *Figure 03*, each sphere is defined as a unique object, each with its respective coordinates in the cartesian grid. Looking at this image from a meshing perspective, consider the number of polygons present in this scene. To display this relatively simple graphic, thousands of polygons must be generated. From a rendering perspective, the lighting simulation must calculate which spheres are reflected on one another, as well as calculate relative brightness of each surface based on a combination of both direct light emanating from the primary light source, and indirect light reflecting off all objects in the scene.

These calculations cost vast amounts of computing power. Specialized hardware with high random-access memory (RAM) and video-RAM (VRAM) are required to perform these tasks. Alternatively, multiple computers may be networked together to share in processing tasks.

For this reason, inherent within the process of creating computer-generated images is the tension between graphic quality and processing power. Graphic quality and polygon mesh resolution can be severely hindered or enhanced depending on the processing power available to the

3D artist.

This obstacle has forged new methods for generating CGI, of which procedural modeling offers many efficiencies. Procedural modeling refers to different methods used to create 3D models and textures from a set of rules. In procedural modeling, instead of identifying each object in *Figure 03* as an individual sphere placed separately in its respective location, a single rule, or procedural algorithm, can be set to control the location of multiple instances of the same sphere within a range of random values of X, Y, and Z.

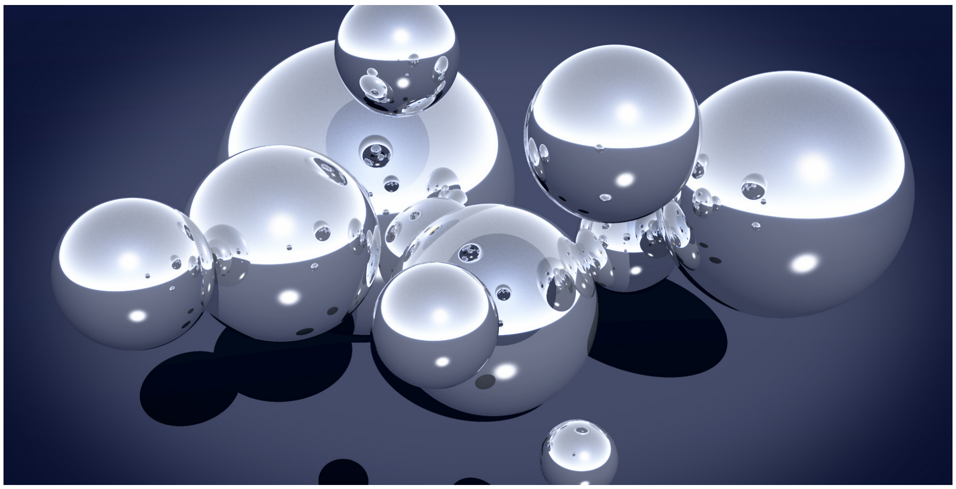


Figure 03. Example of the 3D models on Figure 02 laid out in a scene.

The geometry populated by procedural algorithms is often called an 'instance' or 'seed' of a single rule, which greatly cuts back on the processing power required to generate a scene.

Procedural modeling has multiplied the creative freedom for 3D artists by allowing control over the generation of exponentially complex scenes with geometry which would otherwise be too intricate, tedious, or time-consuming to model. It has opened the door to create increasingly complex environments, including vegetated landscapes of high graphic quality.

FROM THE VERTIGO TITLE SEQUENCE TO TODAY

Early computers did not have display screens, and completed calculations based on rudimentary punch-card readers (*Chopine, A.*). The development of computer graphics, a term coined by pioneer William Fetter, progressed concurrently with the first computer displays. In 1963, MIT student Ivan Sutherland authored a digital sketching program called *SKETCHPAD*, thereby becoming the father of modern day computer graphics. In these early days, the display of 3D models in computers was limited to transparent wire-frames.

In the year 1982 the movie *TRON* was released, which was one of the first films to use a combination of CGI and live action for the entire length of the film. This was also the year Autodesk, one of the world's largest 3D modeling software corporations was founded.

The 1980s and 90s saw a broad dissemination of CGI through multiple industries, including film, medicine, manufacturing, and construction.

A competitor to Autodesk, E-On Software was founded in 1997 and by the 2000s developed a number of 3D modeling software which, unlike traditional Autodesk products, offer fully procedural modeling tools.

The 2010s saw advancements in what is known as machinima software. In traditional 3D modeling, after the scene has been laid out and animation paths are set, the final product has to undergo a phase called 'post-processing'. In this phase, the rendering engine will generate the final still image or video animation. In machinima software, environments are rendered in real-time, without the need for post-processing. Examples of the use of such software include video games such as *Quake* (*Lowood, H.*).

In 2010, E-On Software released a machinima software available to the general public called *LumenRT*. This software has been largely marketed to architecture and related design professions, including urban planning and landscape architecture.

More recently in 2014, E-On software released a fully procedural 3D modeling software called *The Plant Factory* , which is solely dedicated to authoring 3D models of plants.

E-On Software's products have been adopted by most large film studios for use in their CGI production, including Blue Sky Studios, Dreamworks Animation, Sony Pictures Imageworks, Warner Bros. Interactive Entertainment, among many others (*E-On Software).*

Notable examples of complex photo-realistic landscaped environments generated using E-On Software's products include the jungles and forests in the movie *Avatar,* as well as the diverse outdoor sets used in the movie *Minions*.

PROJECT INTENT

This project set out to apply these contemporary 3D modeling and rendering tools to generate landscape design imagery. Using CGI in Landscape design has the potential of improving visualization of outdoor spaces and may complement both design development and the sales process.

To support this intent, the project's objectives were as follows:

- Develop a replicable process & methodology for CGI production.
- Develop an online repository of procedural models available for use by the landscape design community.
- Apply these tools to a real-life project (On With Life project).

METHODOLOGY

LANDSCAPE DESIGN GRAPHIC DEVELOPMENT PROCESS

In a typical landscape design project, after the initial requirements-gathering phase, the project will enter a graphics development phase. First, a diagram of functional relationships, or bubble diagram, is developed to describe the required and desired relationships between different programmatic elements within the project Second, form composition studies are produced, in which the designer can study the scale, layout, and forms that will be favorable to use in the project.

A Preliminary design is then developed, in which an initial 2D plan graphic of the proposed outdoor space can be presented to the client for initial feedback. Finally, after client feedback is incorporated into the design, a final masterplan graphic is produced, which includes all final plant and material selections.

It could be beneficial to incorporate 3D imagery during both the preliminary and final masterplan graphic stages. During preliminary review, 3D graphics can enhance the client's understanding of the space so that they may provide more effective feedback to the designer. In addition, the preparation of these graphics may enable the designer to be more critical of their own work, resulting in a more polished, scrutinized final product.

These graphics could also be incorporated into the final graphics package together with the final masterplan. They could be used to clearly communicate the design with contractors and installers, as well as for fundraising efforts.

CGI FOR LANDSCAPE DESIGN

This project used E-On Software products to develop landscape computer-generated imagery. The process of CGI development can be summarized as follows:

- **Step 1:** Create procedural 3D models of plant material using *The Plant Factory*.
- **Step 2:** Layout a landscape scene populated with plant material using *Vue* or *LumenRT*.
- **Step 3:** Produce still and animated renderings using *Vue* or *LumenRT*.

Note that although *LumenRT* is a machinima software, it has a function to export renderings of its environment and was used for rendering and animation production. The benefits and disadvantages between these two tools will be discussed under the Layout & Animation section.

PROCEDURAL PLANT MODELS

The Plant Factory is a procedural 3D modeling software which was used to generate individual plant models. A total of forty-five (45) distinct species were modeled for this project.

Plant model types ranged from deciduous trees, deciduous shrubs, evergreen shrubs, herbaceous forbs, grasses, bulbs, and groundcovers. Plant selection was focused on specimens hardy to USDA Cold Hardiness Zone 5 and lower.

Anatomical accuracy of plant models is essential to portray a useful representation of an outdoor space. Many plant models currently available for commercial use suffer from a lack of anatomical accuracy. Their overall phenology does not match the mature size, flowering, and growth habit of the species portrayed. This makes it difficult for landscape design professionals to use the plant models available, so that it becomes necessary to build plants from scratch. *The Plant Factory* allows for full control over the scale and size of the plant geometry. The criteria for generating these models was as follows:

- Must be modeled to scale, incorporating variation in mature species and/or specific cultivar size.
- Material maps must be representative of plant coloration and structure.
- Must include accurate depiction of fruiting, flowering, and growth habits.
- Plant structural strength must depict accurate movement under average breeze conditions.
- Incorporate plant appearance features related to seasonal changes.
- Incorporate plant appearance over its entire maturity cycle.

One of the most powerful features of *The Plant Factory* is the ability to build the plant so that its appearance changes based on the its maturity (age) and time of year (season). What will a planting look like when it is first installed? What will it look like in 10 years after installation? 20 years? This feature can enable designers to address such client concerns. Often the only appearance shown to a client is that of a garden in its mature state. This tool makes it possible to display views of a garden through the years and seasons, since the seasonality and aging is built into each plant model.

Figure 04. *Iris sibiricus* 'Caesar's Brother'

Figure 05. *Allium atropurpureum*

Figure 06. This *Salvia nemerosa* 'Machnight' model features correct shoot branching habit in orthogonal pairs. The overall height and spread of the model are true to the mature size of this particular cultivar. Leaves were created by scanning a sample leaf from a live specimen. The forb rosette is created using the hydra tool.

Figure 07. *Alchemila mollis*

Figure 08. *Sesleria caerulea*

Figure 09. *Athyrium filix-femina*

Figure 10. Appearance changes through the seasons from spring to winter is built into this *Echinacea purpurea* 'Merlot' procedural model. Rendered using *Vue*.

Many of the models created for this project are available for download through Cornucopia3D (http://www.cornucopia3d.com/).

LAYOUT & ANIMATION

Once all the plant models were created,the next step was to lay them out within a scene. Software used to perform this task are *Vue* and *LumenRT*. Before the models can be imported to these programs, they have to be exported into the appropriate format.

For use in *Vue*, the export choice with the greatest editability is to export the as a "Vue Species" or .TPF format. This format allows for full integration of the plant model inside of *Vue*.

Alternatively, the plant models can be exported as "LumenRT Objects" or .LOB format. Because *LumenRT* is a machinima software, the full complexity of a procedural model is lost during export. *LumenRT* objects exported form *The Plant Factory* loose all seasonality and aging parameters.

In *Vue*, each time a plant is placed in the scene, it places a different 'seed' or procedural instance of the original model so that no two seeds are exactly alike (see *Figure 12*). *Vue* also affords the flexibility of inserting plants individually, painting plants onto topography with a paintbrush, or applying them to any object as an "Ecosystem material."

Figure 11. Scene rendered in *LumenRT*. Note the identical copies of Sesleria autumnalis in the foreground.

Although *Vue* produces still images and animations of greater graphic quality compared to *LumenRT*, post-processing continues to be an intensive process requiring optimal hardware specifications. *Vue* would be most effective when post-processing can be done either through a render farm (local networked machines that share in post-processing tasks) or through cloud computing, where machines networked in the cloud could perform post-processing tasks and send back a finished rendering to the primary user. Several cloud rendering services for *Vue* are available online.

In *LumenRT,* imported plant models are of identical instances of one another, reducing processing overhead by sacrificing the more realistic aesthetic of random seeds. This drawback is balanced by the ability to navigate rendered environments in real time, and overall ease of use. Video animations measuring 640 x 480 pixels animated at 30 frames per second were rendered by LumneRT's rendering engine at an average rate of 52 frames per hour using a machine equipped with 4096MB of graphics memory and 2048MB dedicated video memory.

Figure 12. Scene rendered in *Vue*. In this scene, plants are populated by creating a simple "Ecosystem material" which places equal parts of *Rudbeckia fulgida* and a simple grass at 100% density on a 14'x30' rectangular surface near the foreground. Note the variability within each *Rudbeckia fulgida* "seed".

CASE STUDY: THE ON WITH LIFE SENSORY GARDEN AND THERAPY GROUNDS

These graphic tools were put to the test in a real-world landscape design project, the On With Life Sensory Garden and Therapy Grounds.

On With Life (OWL) is a brain injury rehabilitation center located in Ankeny, Iowa. Between 2014 and 2015 they have been undergoing a major renovation project to update and add to their current facilities. The new addition will house a new Outpatient Center, therapy pool, expanded dining room and therapy areas, additional person served rooms, multi-purpose rooms , and outdoor space. As part of this project, the Advanced Landscape Design Composition Studio from the ISU Department of Horticulture was invited to design a new Sensory Garden. This garden would serve as part of the therapy grounds for brain rehabilitation residents.

The program document outlined the following criteria for this new outdoor space:

- Interwoven paths to accommodate persons served of varying degrees of endurance.
- A central hub to serve as a sheltered destination and outdoor therapy space.
- A putting green with artificial turf and a rough.
- An amphitheater for group activities
- A water feature
- Exercise stations that allow 2 or more to participate in walking or range of motion activities, wheelchair swing area.
- Stairs up, bridge across
- A butterfly garden, birdhouses
- A Children's play area, some adult exercise equipment- range of motion
- Fruit trees and multi-level gardens, herb pots
- A music area, Zen garden

Three designs were developed as group projects and were presented by each student team to the *On With Life* executive board for final selection.

DESIGN CONCEPT

The final design selected was inspired by the different regions of the brain– specifically how each region relates to the functional activities we carry out on a day-to-day basis. Unlike a neurologically healthy person, patients admitted to the OWL Rehabilitation Center may not be able to effectively utilize one, or several, of these brain regions due to previous traumatic brain injury. To facilitate the reactivation and rehabilitation of these specific brain regions, this healing garden design is divided into distinct areas that encourage activities that engage a specific region of the brain.

DESIGN PROGRAM

The Frontal Lobe Garden. A recreational area containing a playground, exercise equipment, a basketball court, and a putting green; engages motor skills and promotes skeletal & muscle movement.

The Cerebellum Garden. A farm and construction-like area that contains several "activity stations" such as a gravel digging pit, railroad tracks, curbed & stair areas, which engages fine motor & muscle control skills.

The Occipital Lobe Garden. A butterfly garden featuring colorful flowers and other bird and butterfly-attracting plants.

The Tempo-ral Lobe Garden. Incorporates the serenity of Zen garden design and soothing sounds of soft instruments to improve hearing and memory skills.

The Parietal Lobe Garden. Features handicapped-accessible, raised beds capable of growing fruits and vegetables.

The Olfactory Bulb Garden. Utilizes aromatic plants and herbs to engage smell.

The Hippocampus. Utilizes comfort of an overhead structure and amenities to create a 'hub' centrally located within the therapy grounds. It features tables for outdoor speech therapy, and plant signage for memory exercises.

LANDSCAPE GRAPHICS

The purpose of creating a CGI landscape graphics package after the final masterplan had been completed was to aid in fundraising efforts. For this project, the computer-generated imagery is intended to inspire donors and investors into helping the *On With Life* staff meet the budget required to complete construction of the therapy grounds.

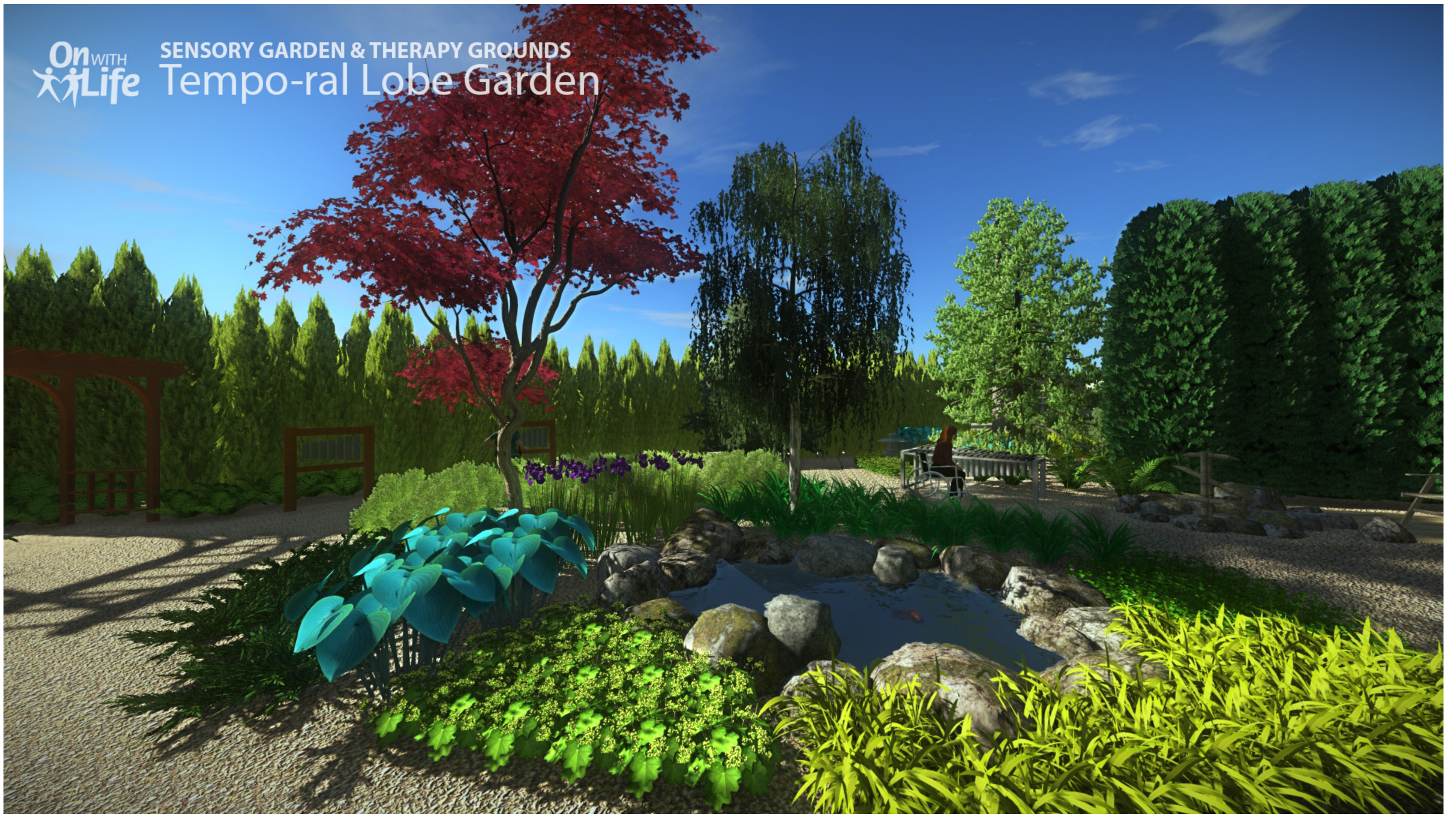
The landscape graphics package developed for this project included two still renderings, which are featured on the next page, and two animated walkthroughs. Both animations were rendered in *LumenRT* at a high-definition resolution of 1280 x 720 pixels at 30 frames per second for a total 1,680 frames.

As of April of 2015, On With Life is on schedule to meet their fundraising goals and break ground on their therapy grounds starting in the late summer of 2015.

Figure 13. (Next page, top) Still rendering of the entry patio bed at the Parietal Lobe Garden.

Figure 14. (Next page, bottom) Still rendering of the island bed at the heart of the Tempo-ral Lobe garden. Some of the musical instrument stations are features in the background.


On with Life
SENSORY GARDEN & THERAPY GROUNDS
Parietal Lobe Garden
The Zealous Thumb
Realizing Your Landscape


On with Life
SENSORY GARDEN & THERAPY GROUNDS
Tempo-ral Lobe Garden

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