

# Building a 3D Object Library for Visualising Landscape Futures

**Pettit, C.J.<sup>1</sup>, F. Sheth<sup>1</sup>, W. Harvey<sup>1</sup> and M. Cox<sup>1</sup>**

<sup>1</sup> *Future Farming Systems Research Division, Department of Primary Industries, Victoria*  
Email: [christopher.pettit@dpi.vic.gov.au](mailto:christopher.pettit@dpi.vic.gov.au)

**Abstract:** Geographical visualisation is an extremely powerful communication tool for better understanding landscape processes, functions and futures. Visual communication is an increasingly common part of environmental decision-making, being used as a ‘common currency’ to facilitate dialogue between policy-makers and non-experts to increase understanding and thereby improve the decisions made. In recent years we have witnessed the proliferation of geographical visualisation technologies such as digital globes, virtual worlds and game engines. Such technologies provide a powerful front-end to spatial datasets and models and support policy-makers, planners and communities to make better land management decisions. In order to create collaborative virtual environments where end users can fly-through landscapes and interact with one another in a virtual world there is a need for realistic, accessible and contextualised three-dimensional (3D) objects. Collaborative virtual environments typically comprise: vegetation (trees, shrubs etc.), people (avatars), animals (domestic, wild) and built infrastructure (buildings, farm equipment, street furniture). Such 3D objects are the basic building blocks for creating a collaborative virtual environment. This paper reports on the development of a 3D object library which comprises flora, fauna and built infrastructure objects which can be used to create Australian virtual landscapes. The 3D object library is accessible through the Victorian Resources Online (VRO) website and is an online resource for scientists, students and communities to assist in building geographical visualisation products. Further research is necessary in working towards a robust 3D spatial data infrastructure to better support the storage management and dissemination of such information.

**Keywords:** *Geographical Visualisation, Landscape Management, 3D Models*

## 1. INTRODUCTION

In understanding sustainable and productive landscapes there is a need to better communicate land management practices and the implication of these practices with policy-makers, planners, land managers and the broader community. An underlying data infrastructure for visually representing current and future Australian landscapes is urgently required. Historically, various methods have been used to illustrate proposed or potential changes to the landscape, including computer-generated visualisations. Such images are increasingly generated from three-dimensional (3D) object databases, and the growing accessibility of this technique is due to continued improvements in the price, capability and availability of computer hardware, visualisation software, and supporting 3D object libraries. Over the last 5 years The Victorian Department of Primary Industries (DPI) has developed a 3D object library comprising flora, fauna and built structures. These objects are held in an online database which can be accessed to create 3D landscape scenes. The object library comprises over 120 objects which are currently housed on the Victorian Resources Online (VRO) geographical visualisation website [http://www.dpi.vic.gov.au/vro/3d\\_object\\_library](http://www.dpi.vic.gov.au/vro/3d_object_library).

There are two objectives this body of research aims to address:

- Develop a systematic 3D object library data collection program and supporting database infrastructure,
- Provide a 3D object library resource to support the creation of 3D landscape scenes.

In this paper we will first provide a brief review of 3D objects and supporting library resources. We will then discuss our current methodology for building 3D objects. The 3D object library will be presented as an exemplary free 3D object resource for the geographical visualisation community to use. We conclude the paper by discussing some future research directions including how we might test the usability and usefulness of the library as an underlying spatial decision support infrastructure.

## 2. A BRIEF REVIEW OF 3D OBJECTS AND SUPPORTING LIBRARIES

### 2.1. 3D Object Models

3D objects can be defined as visual representations of the elements that comprise real and fictitious geographies (Pettit & Wu, 2008). 3D objects are the fundamental building blocks used to create landscape scenes, virtual worlds, movies and animations. 3D objects are used to visually represent flora, fauna, built infrastructure and people (avatars). Groups of 3D objects can be used to create icons or tiles, for example the land-use icons developed by Rodriguez *et al.* (2008) for representing climate change futures. There are also many 3D modelling tools available to support the creation of objects including 3D Studio max, sketch-up, blender and 3D programming languages such as VRML and x3D. In fact the art or science of creating 3D models is becoming increasingly sophisticated as end users wish to view highly realistic geographical visualisation products.

One of the major challenges in rendering of 3D object models, in particular vegetation, is that the large number of polygons needed to model them individually or in fact as groupings (such as a forest) exceeds the limits posed by the current rendering hardware. Rendering methods should therefore apply simplifications (O.Deussen, P.Hanrahan *et al.* 1998). To classify these simplification approaches, we can define specific scales of simulation at which rendering should provide the required level of realism:

- Insect scale: A consistent, realistic depiction of individual branches and leaves is expected. The images of individual leaves should exhibit parallax effects when the viewer moves, including the perspective shortening of the leaf shape and its texture, and view dependent occlusions.
- Human scale: Scenes must look realistic through distances ranging from an arm's reach to some tens of metres. Consistency is desired but not required.
- Landscape scale: Individual trees or other objects are almost never focused upon and consistency is not required. Viewing distance may exceed several hundred metres.

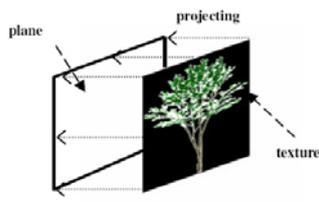
By considering this virtual scale one can decide the type of model that needs to be used to create a landscape scene or virtual environment. There are three general approaches for achieving satisfactory visualisation results: image based models, billboard clouds and 3D functional models.

#### Image Based Models

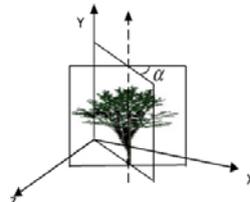
Billboards are the simplest type of objects. The billboard idea is simply to present some model using only one or two textured rectangles (Akenine-Moller and Haines 2002). Using billboards, 3D models are simplified onto a set of planes with texture and transparency maps. If only one rectangle is used it is always rotated to face the camera directly. The texture used remains the same regardless of viewing angle and only

shows one angle of the object. When two rectangles are used they are placed to form a cross and they are not rotated to face the camera. This method is often too coarse to provide accurate visual representation for complex objects, but has been widely used especially in landscape and human scale visualisations.

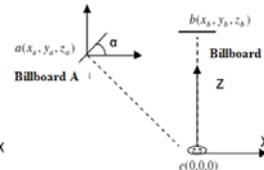
In creating billboards we first replace large sets of faces by a texture plane which is generated by projecting a texture on a plane (Figure 1). Then we rotate the plane to adapt to the viewpoint (Figure 2). In order to avoid the shortening of the visible image when the user looks at it from a range of viewpoints, the billboard plane is always turned towards the camera. Although this simple trick solves the shortening problem, it is also responsible for the main drawback of the method. The tree always looks the same no matter from where we look at it. This missing parallax effect makes the replacement too easy to recognise if the angle  $\alpha$  (Figure 3) is greater than  $20^\circ$ . Figure 4 shows billboard rendering in a 3D scene.



**Figure 1.** Image Projection



**Figure 2.** Rotation of Image Plane



**Figure 3.** Missing Parallax

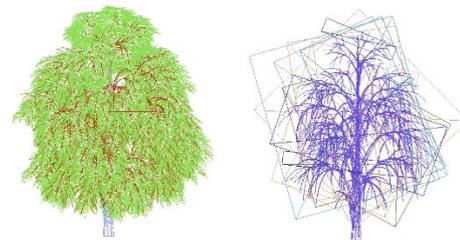


**Figure 4.** Billboard in Realistic Landscape

The  $\alpha$  can be defined as:  $\alpha = 90^\circ - \tan^{-1}(X_a/Z_a)$ , where  $(x_a, y_a, z_a)$  is Billboard' coordinate (Yang, Qing et al. 2004)

### Billboard Clouds

Billboard clouds are an extension to the standard image based models which can show more geometrical detail from 6 intersecting planes. This is a new approach for extreme simplification in the context of high polygon models like vegetations and real-time rendering. The idea of billboard clouds is to intelligently select a minimal set of suitable planes so that static 3D model's geometry is fully covered (Decoret, Durand et al. 2003). These polygons surround the model and represent a defined part of its geometry from every plane's point of view. For example, Figure 5. shows the basic idea of the proposed method: the original tree defined by a hundred thousand polygons is approximated by a few fixed billboards, where a single billboard itself approximates many leaves.



**Figure 5.** Structure of Polygonal and Billboard tree

### 3D Functional models

A 3D functional model can be created through mathematical techniques based on the principles of geometry and/or fractals. Geometric models can be developed using a mathematical wire frame representing a number of polygons in a 3D dimensional virtual space. They can then be displayed as a two dimensional image through a process called 3D rendering and can be created automatically or manually.

3D fractal model are complex shapes based upon repeating patterns of other shapes. These other, or inner, shapes are often quite simple, but when linked repeatedly in a patterned manner they generate a complex outer form (Figure 6). Lindemayer invented a mathematics based on graph grammar rewriting systems to describe iteratively branching structures; these were named in honour of him and are referred to as L-systems (Prusinkiewicz and Lindenmayer 1990). Fractal tree generation is a technique for defining complex objects by successively replacing parts of a simple initial object using a set of rewriting rules or productions. Figure 6 illustrates how a simple example of how the 3D complex fractal plant works.

If the variables: X Y

Rules : (X → XY), (Y → X) which produces:

```

n=0:   X
       /\
n=1:   X Y
       /\
n=2:   X Y X
       /\ | \|
n=3:   X Y X X Y
       /\ \| \| \|
n=4:   X Y X X Y X Y X
    
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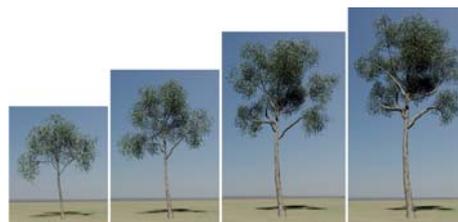


Figure 6. 3D Fractal Tree Model

## 2.2. Available 3D Object Libraries

There are a number of online 3D object library repositories or galleries where objects can be either purchased or freely downloaded. In fact a Google search results in 342,000 hits on the search term “3D object library” (07/03/09). In this section we review a number of these online 3D object libraries. Such libraries can be categorized as either free or for purchase, open or proprietary standard.

3DNWorld (<http://www.3dnworld.com/>) contains a number of downloadable components including: terrain, land cover, water, sky, light, and 3D objects native to the Visual Nature Studio and World Construction set visualisation software packages. The site includes a small number of VNS proprietary standard freely downloaded 3D objects representing houses, trees, wind turbines etc.

The Google 3D Warehouse (<http://sketchup.google.com/3dwarehouse/>) is another free online 3D model sharing platform. There are two types of models found in Google 3D warehouse: geo-referenced and non geo-referenced. A geo-referenced model is a building or other real world object which has been accurately located in Google Earth and published in the 3D warehouse. Non geo-referenced models are not locatable within virtual globe browsers such as Google Earth. The Google 3D warehouse is arguably the largest freely available 3D object library on the Internet. The 3D object library comprises over 49,800 houses, 4000 trees, 1,100 animals and 6,000 people (avatars). Google 3D warehouse supports the COLLADA file format for storing and exchanging 3D models. COLLADA is a COLLABorative Design Activity for establishing an open standard digital asset schema for interactive 3D applications. COLLADA defines an XML database schema that enables 3D authoring applications to freely exchange digital assets without loss of information.

3D Café (<http://www.3dcafe.com/>) includes a mix of free and for purchase objects across a number of file formats including: max, prj, 3ds, dxf, wrl. There are an extremely limited number of free objects. Another online source of 3Dmodel is turbo squid ([www.turbosquid.com](http://www.turbosquid.com)). Turbo Squid is an online marketplace hosting the largest collection of 3D models, motion capture files, textures and shaders assembled. They sell models in a variety of formats including, but not limited to, 3DS MAX, Lightwave, XSI, AI, Autocad, Flash, Direct X, Cinema 4D, Maya and .3DS. Turbo Squid also offers custom packaged memberships. You can choose how many 3D models you want to download as well as meshes, textures, audio files and 2D images.

ESRI has developed an in-house 3D symbols library to support the 3D Scene extension to ArcGIS. You can import 3D models from other formats, such as OpenFlight (.flt), SketchUp (.skp), 3ds max (.3ds), or VRML (.wrl). There are a number of objects representing trees, cars and light poles etc. as multipatch graphics at key locations. ESRI 3D symbols library is fully proprietary and obtainable only when purchasing a copy of ArcGIS software.

Lenne 3D (<http://www.lenne3d.com/index.php>) is a company offering services in the area of digital botany and landscape visualisation. The 3D plant database Flora3D provides multi level detailed plants for real time rendering and display processing. Other real time options of 3D plants are always a trade-off between their appearance and level of detail with respect to camera distance. Flora 3D models can be access by their free rich internet client Marché3D. This database allows users to purchase Flora3D plants, which are delivered with species and metadata (XML based). The Flora3D models then drag and drop in ArcGlobe or ArcScene with the help of Déjàvu3D Toolbar provided by Leene3D (Paar, Rohricht et al. 2008).

SpeedTree (<http://www.speedtree.com/>) is a programming package produced by Interactive Data Visualization, Inc. (IDV) that generates virtual foliage in real time for video games and simulations. SpeedTree, is a C++ middleware library designed to facilitate the rendering of real-time trees and plants that have been created with SpeedTreeCAD, the designer tool that is packaged with the SpeedTree SDK. Plants

produced with SpeedTreeCAD maintain a small memory footprint and low run-time load. The source data of SpeedTree is saved in .SPT file. .SPT files are “binary procedural definitions” of trees created and edited with SpeedTreeCAD. These files are loaded by the API, and provide a resource to the tree’s geometric data. SpeedTree vegetations species could be used in third party commercial 3D packages (3DS Max and Maya) and gaming consoles (Xbox360 and PS3). It has an online vegetation library comprising approximately 130 objects that can be purchased as libraries comprising 33 different tree species.

All above listed sources of 3D models have been reviewed against their price, proprietary and format source. The main difference between free and paid models is the quality of the model. Most of the freely available models are not as good as paid models (Lenne 3D), but this is not necessarily true for Google Warehouse. It has wide range of good quality models but here the texturing can be an issue when exporting objects to other file formats. Only Google is using an open source format for their 3D model, which is an attractive feature to object developers where all other sources either have their own developed format for example Lenne 3D, or commercial formats which can not be modified.

### 3. THE VICTORIAN 3D OBJECT LIBRARY

On reviewing the available 3D object library resources it has been found there is a deficiency of 3D objects which are representative of Australian landscapes. In Victoria there has been some research efforts made across the Department of Primary Industries (DPI) and Department of Sustainability and Environment (DSE) to begin addressing this deficiency (Pettit & Wu, 2008; and Mansergh *et al.*, 2008). In building the Australia 3D object library there is an image acquisition and processing stage and there is also the storage management and hosting of the 3D object library.

#### 3.1. 3D Object acquisition and construction

DPI Victoria is undertaking an object library acquisition program in order to capture those objects which represent the Victorian landscape and farmscapes. Phase I of the image acquisition program involves capturing those objects which are representative of landscapes comprising the Glenelg Hopkins and Corangamite Catchment Management Authorities (CMA) regions in South West Victoria. The schedule of images and object for capture has been developed according to the following process:

Firstly, The ecological vegetation classes (EVCs) and significant landscapes comprising the Glenelg Hopkins and Corangamite CMA regions have been reviewed. A map with an EVC layer has been produced and the most common and distinctive plant, animal and built objects have been identified – see Figure 7. These classes have been selected on the basis that more than 100,000 hectares of these land-uses occur within the combined regions. A list of key plant species has been derived from the assessment of species lists for the predominant EVCs within the regions. This assessment included the discrimination or removal of species (particularly herbs and forbs) that would blend into a visualisation background. Only those species that were distinctive (i.e., on colour and density of flowers) and had greater potential to stand out or characterise landscapes have been included. An analysis of the significant landscapes within the South West Victoria region shows a number of predominant land use classes in accordance with the Australian land use mapping (ALUM) classification schema. Predominant land use classes include: cropping, grazing modified pastures, grazing natural vegetation, national park, other conserved areas, production forestry and roads and roadsides. A number of field trips have been undertaken to acquire the necessary photographic imagery required to represent those EVCs and land use classes comprising the region – see Figure 7.

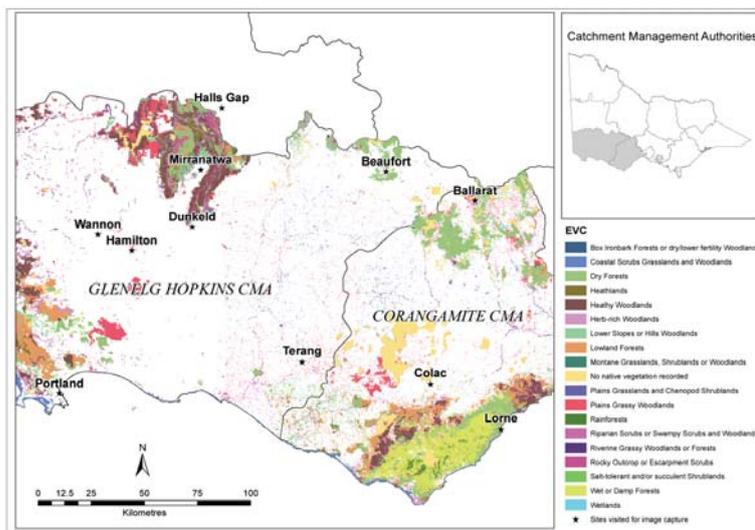


Figure 7. South West Victoria Region – initial area of image acquisition

Field work has been undertaken using a Ricoh Caplio 500SE camera with GPS to capture geographic location. Also, the camera records the time and date of images acquired. The development of metadata for each object has been undertaken by combining the EVC description and camera descriptors (time, date location). Once the photos have been captured the background noise is removed using the Adobe Photoshop package. The next part of process requires quality assurance of the objects to ensure the correct species and description is annotated. This involves identification of the plant found by firstly validating via the DSE EVC website and next obtaining final validation through a meeting with an ecologist within DSE, DPI or the CMA. Once objects have been validated they are converted into 3D objects and both the images and 3D objects are uploaded on the object library database.

### 3.2. Hosting the 3D object Library

The Victorian Resources Online (<http://www.dpi.vic.gov.au/vro>) website has been a natural resource information repository since 1998 with nearly 10,000 pages of online content. Within this resource is the geographical visualisation portal (<http://www.dpi.vic.gov.au/vro/geovis>) comprising links to other visualisation resources, publications, video clips, and also the 3D Object Library. The original version of the 3D Object Library (Figure 8) was developed out of the Our Rural Landscape (ORL) program. The original concept was developed using Extensible Stylesheet Language Transformations (XSLT) to display 3D object data stored in Extensible Markup Language (XML) format. A number of problems with the original build were encountered. It was not possible to retro fit the original library to comply with Department and State Government web standards and a decision was made to build version two of the web site to meet compliance (Figure 9).

All content published to the DPI external website must comply with DPI and Whole of Victorian Government (WoVG) website style and content accessibility guidelines. Content also needs to be published using DPI’s Lotus Domino based Web Content Management System (WCMS). This procedure although restrictive means content is always represented in a consistent manner and has a familiar visual appearance. The second version of the 3D Object Library was developed by analysis of the original concept with a more user-centric approach. It was decided that separating the application into a frontpage and four separate object categories with consistent DPI navigation would lead to an improvement of the user experience. The new frontpage was designed to improve on the original idea but to make it easier for users to find what they are looking for.

We included an explanation of what users can expect to discover in this section and we also explain some basic information about the objects and which software or browser plug-in needs to be installed in order to view an object. We also included three short example video clips as a way of providing users with examples of the quality of the objects without them having to download or install any software to the local computer. We have also included these example videos within the DPIGeoVis channel on YouTube (<http://www.youtube.com/user/DPIGeoVis>). The objects from the original version were then categorised into four broad category groups based on a Departmental thesaurus of terms already in use within sections of the VRO website. Objects were then placed in the most suitable category group - Vegetation, Animals, Built Structures and Rural Landscape. There are currently 120 objects uploaded onto the object Library.

## 4. DISCUSSION AND CONCLUSIONS

A 3D object library is a way of storing and managing 3D object models in a database structure which ultimately support the creation of landscape scenes and virtual worlds. Historically, various methods have been used to illustrate proposed or potential changes in the landscape, including maps, photomontages and



Figure 8. Original Version of 3D object Library

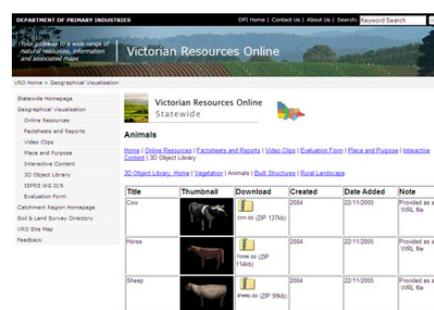


Figure 9. Current Version of 3D Object Library

computer-generated visualisations. Such visual depictions are increasingly generated from 3D object databases. Although visualisation software is being developed with ever greater capabilities for realism, there is often a lack of correspondingly detailed 3D object data to support the generation of 3D landscape scenes. Relatively little work has been done in evaluating the effects of increased realism on the perceptions of those viewing the visualisations which is one of the challenges being addressed in our broader research program. Through our investigations we have found that most of the 3D objects found on the web today are not developed to the detail and purpose required and there existing few 3D object resources to support the growing geographical visualisation community. There is even more limited body of research in developing 3D object models and support libraries which can be access to create virtual representations of Australian landscapes. In this paper we have attempted to begin addressing this deficiency through the development of an Australian 3D object library and through the provision of a brief critical review of available 3D object resources.

## 5. FUTURE RESEARCH

Our research in this area is on-going and we aim to improve and build on the existing 3D object library in a number of areas. Firstly, future research is being undertaken in collaboration with the University of Melbourne, and DSE through the Collaborative Research Centre – Spatial Information (CRC-SI) in developing a taxonomically determined database to enable the automatic uploading of 3D objects from a wider range of 3D object builders. Secondly, we are working on supporting a number of files formats so that end users can more easily import objects into a number of geographical visualisation products including geographical information systems (GIS), digital globes and computer game engines. Thirdly, we are looking at creating iconic tiled landscape representations similar to the Simcity approach as undertaken by Rodriguez *et al.* (2008). Such an approach will ultimately support the automated visualisation of raster based land use change and impact models. Finally, we are developing a way to formerly test the usability and usefulness of the library as an underlying spatial decision support infrastructure. It is anticipated that this evaluation approach will utilise online statistics made available through products such as Google Analytics. Ultimately, the 3D object library will provide a resource to geographical visualisation practitioners for creating 3D landscape scenes as part of a participatory approach to envisioning landscapes, past, present and future.

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