Developing 3D contents for e-learning applications

RODRIGUES, Marcos <http://orcid.org/0000-0002-6083-1303>

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Marcos A Rodrigues  
Geometric Modelling and Pattern Recognition Research Group - GMPR  
Sheffield Hallam University, Sheffield, UK  
m.rodrigues@shu.ac.uk  
www.shu.ac.uk/gmpr

DEVELOPING 3D CONTENTS FOR  
E-LEARNING APPLICATIONS
Motivation for 3D Imaging

3D Imaging can provide:

- Realistic models
- Interactive visualization and manipulation of objects on screen
- Sense of immersion in a 3D world
- Unique opportunity to explore objects and relationships
- Control over how objects are displayed
- A variety of interrogation dialogues as opposed to a fixed script
- Better recall of learning experience from a visual and spatial environment

These lead to enhanced learning experiences
Some Limitations of 3D Imaging

- Web browsers do not understand 3D models
- Current methods are too slow to be used in a realistic scenario within a web browser
- Problems of data representation, compression, processing time
- Need a number of techniques to generate 3D models

Our needs are for real-time, responsive interaction with 3D scenes within a browser
Existing Option

Client Browser \[\rightarrow\] Server-side Scripting Language \[\leftrightarrow\] Server

\[3D\text{ data}\]
Some Problems with this Approach

- If the scene is to be rotated or translated the server has to calculate new pixel values for the displayed image
- Too much overhead communication between client/server
- The burden is mostly on the server, uneven load (fat server and thin client)
- Works well for 2D images, streaming audio and video, and text data from databases

A workable solution for interactive 3D would be to place the load on the client machine taking advantage of the underlying hardware thus reducing overhead communication
A Workable Solution

Client Browser

[Diagram showing client-side scripting language and 3D data exchange]

Server

3D data

Client-side Scripting Language

3D data
The Obvious Options (1)

JavaScript
- Client-side scripting language
- Developed to add dynamic content to web pages
- JavaScript statements are embedded into HTML code
- Compatible with all browsers
- The most popular scripting language on the Internet

Thus, potential for easy integration of 3D contents into a web page
The Obvious Options (2)

OpenGL
- The industry standard for high performance graphics
- Comes pre-installed on all major operating systems (Windows, Mac, Linux, Unix)
- Runs on the client machine taking advantage of graphics hardware
- Developed in C/C++ so it requires some programming knowledge to be able to drive the OpenGL API
- Vast number of tutorials on the web

However, since we just want to include interactive 3D models on the web we may not want to learn OpenGL at all!
The problem at this conjuncture is that JavaScript does not understand OpenGL.
The Mozilla Approach

- The future of the web is augmenting 2D content with the 3\textsuperscript{rd} dimension
- Khronos: a 3D web project seeking to create standards for 3D solutions development
- The aim is for end users to take advantage of those solutions as part of the normal web experience
- Standards are expected to be published by May 2010
- The approach
  - To develop an OpenGL wrapper within JavaScript
  - Effectively, a JavaScript extension
  - The browser will come pre-installed with all necessary plug-ins

It is not clear which range of 3D formats will be supported
The Google Approach

- Same reasoning and motivation as Mozilla
- Differs in implementation details
- Much further down the line in the development process
- An API is already available with good documentation: O3D
- The approach
  - To develop an OpenGL wrapper within JavaScript
  - Effectively, O3D is a JavaScript extension
  - Plug-ins are required

Google has opted to support the COLLADA format for 3D contents, but this still needs conversion to O3D notation
The O3D Solution

Source: http://code.google.com/apis/o3d/docs/techoverview.html
The O3D JavaScript Extension

- O3D is an open source JavaScript extension
- The O3D API provides interactive web based applications
- Interfaces with OpenGL
- Harnesses the power of the client machine
- Available for Windows, Mac, Linux
Creating a 3D Scene

- With O3D we can:
  - Import 3D scene models; or
  - Create *transform graphs* from scratch

- Transform graphs specify the colour, normals, effects, and the position of objects in 3D space

- We can also use a combined approach, importing some models and adding others from scratch
Importing 3D Contents to O3D

Source: http://code.google.com/apis/o3d/docs/techoverview.html
Tools Required

- The O3D plug-in
- A 3D modelling package that can export to COLLADA format
- A COLLADA file converter to .o3dtgz (provided by O3D API)
- An html editor to include O3D JavaScript commands to load and display data
Example: Creating 3D Contents

- Start your favourite 3D modelling package
Create a Model and Export to COLLADA Format

My First Model

The exported file has the extension *.dae (Digital Asset Exchange)
Convert the Model to JSON

The file has now the extension `.o3dtgz` (Tar-Gnu-Zipped) and can then be displayed on the browser.
Viewing and Interacting with the Model on a Web Browser
Not a Single OpenGL Low Level Construct is Required

```cpp
glBegin(GL_TRIANGLES);

glColor3f(1.0f, 0.0f, 0.0f); // Red
glVertex3f(0.0f, 1.0f, 0.0f); // Top Of Triangle

glColor3f(0.0f, 1.0f, 0.0f); // Green
glVertex3f(-1.0f, -1.0f, 1.0f); // Left Of Triangle

glColor3f(0.0f, 0.0f, 1.0f); // Blue
glVertex3f(1.0f, -1.0f, 1.0f); // Right Of Triangle

.....

glEnd();
```

However, O3D provides the equivalent OpenGL constructs (transform graphs) as above giving the developer the option for a combined approach
O3D Sample Code

```html
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN" "http://www.w3.org/TR/html4/loose.dtd">
<html>
<head>
<title>Web Browser 3D Scene Viewer</title>
</head>
<body onload="init();" onunload="uninit();">
<script type="text/javascript" src="../o3djs/base.js"></script>
<script type="text/javascript">

function onRender() {
    g_viewInfo.clearBuffer clearColor = [0.8, 0.95, 0.8, 1];
    setClientSize();
}

function initLoadFile(clientElements) {
    var path = window.location.href;
    var index = path.lastIndexOf('/');
    path = path.substring(0, index+1) + 'assets/myfirstmodel.o3dtgz';
    var url = document.getElementById("url").value = path;
    g_loadingElement = document.getElementById('loading');
    
    ...
}

</script>
</body>
</html>
```
A 3rd Way of Acquiring 3D Models
A Number of Alternative Projection Methods Can Be Used

The camera and projector can be parallel or angled, and coding schemes can vary.
Our 3D Striper Method

A series of parallel stripes are projected onto a surface of an object. Stripe information is used to reconstruct a point cloud in 3D space.
The projector determines the centre of the system
Geometrical Relationships

\[ z = \frac{W_n}{D_p} \left( D_p - D_p + \frac{D_p D_s}{vPD_p + W_n} \right) = \frac{W_n D_s}{vPD_p + W_n} \]

\[ \frac{W_n}{D_p} (D_p - x) = D_s - vP(D_p - x) \quad \Rightarrow \quad x = D_p - \frac{D_p D_s}{vPD_p + W_n} \]

\[ \frac{y}{D_p - x} = \frac{hPF}{F} \quad \Rightarrow \quad y = hP(D_p - x) = \frac{hP D_p D_s}{vPD_p + W_n} \]
Stripe Indexing and Generation of 3D Data

captured image  (1) locate stripe pixels  (2) index stripes  (3) map to 3D space

quadrilateral structure in the indexed stripe pixels

⇒
Problems with Occlusion
Unsolvable Occlusion Problem
Sub-pixel Estimation

(a) black stripes located between white ones
(b) result on the reconstructed surface
The Effects of Computing White and Black Stripes
Texture Mapping
Performance

- 3D reconstruction in 40ms
- Only a single 2D image is required per model
- Can operate at video frame rates
- Also suitable for 3D animation from video frames
- It requires post-processing (hole filling, smoothing, noise removal)
- Sound can be integrated from video footage
Future work

- Hardware issues
- Embedding the design into DSPs
- Methods for 3D image compression
- Built-in exporters
  - 3D data -> COLLADA -> o3dtgz
  - 3D data -> COLLADA

3D data -> COLLADA
Related work: Feature extraction & recognition