ROYAL INSTITUTE OF TECHNOLOGY

DH2323 DGI15

INTRODUCTION TO
# COMPUTER GRAPHICS AND INTERACTION

# IMAGE-BASED RENDERING AND ANIMATION

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Based on DGI12 notes by Carl Henrik Ek

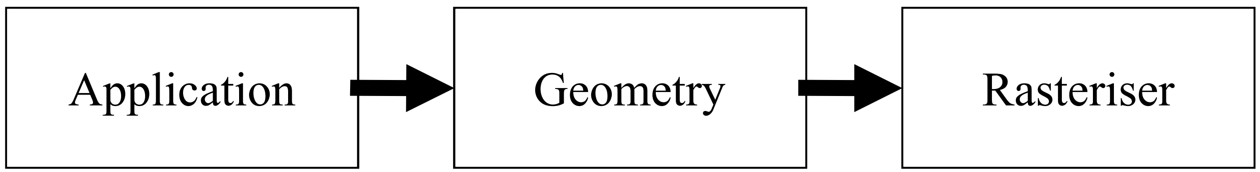
# Graphics Pipeline Architecture

Can divide pipeline into three conceptual stages:

*Application* (input, animations, think SDL)

*Geometry* (transforms, projections, lighting)

*Rasteriser* (draw image as pixels)



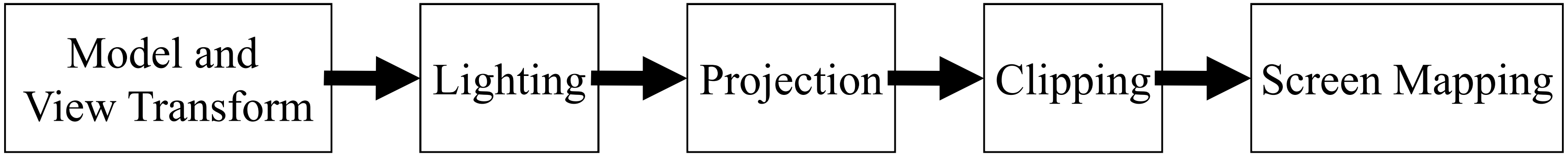

These define the core structure of the pipeline

# Geometry Stage

Responsible for polygon and vertex operations

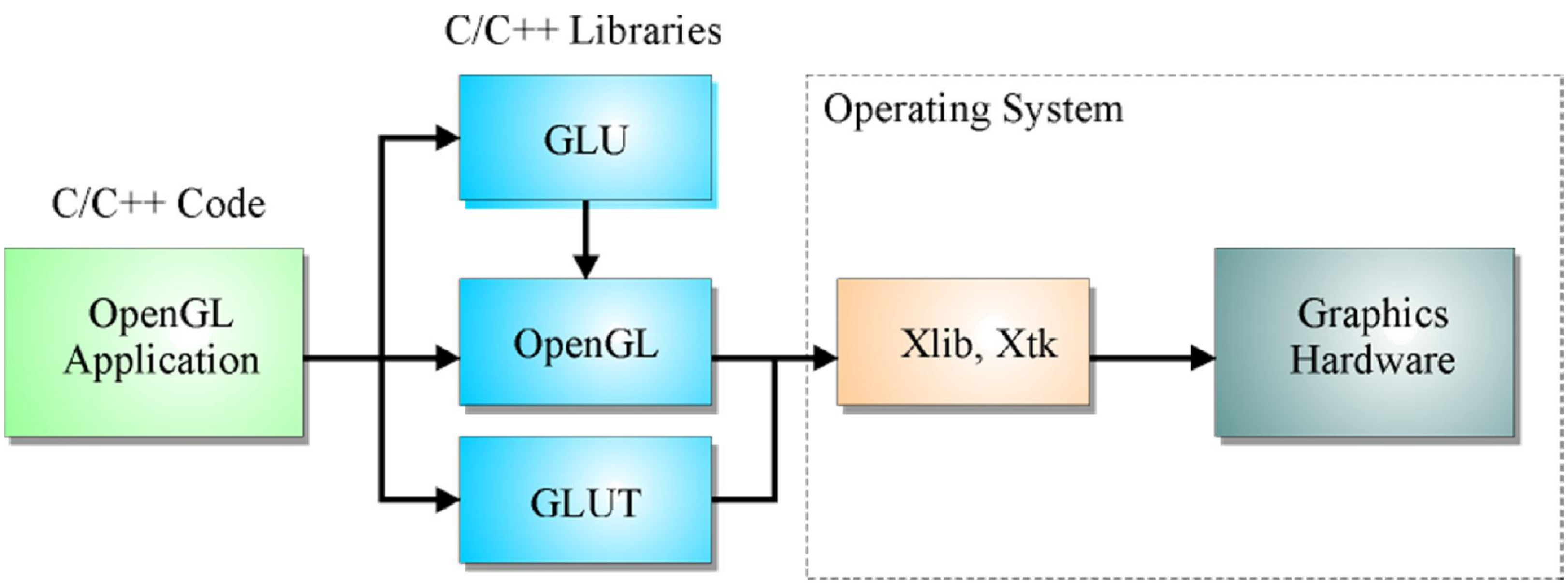
Consists of five sub-stages:

- Model and View Transform
- Lighting and Shading
- Projection
- Clipping
- Screen Mapping



# What is OpenGL ?

- Software interface to graphics hardware
- Commands for interactive three-dimensional graphics
- Hardware independent interface
- Drawing operations performed by underlying system and hardware



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# I.

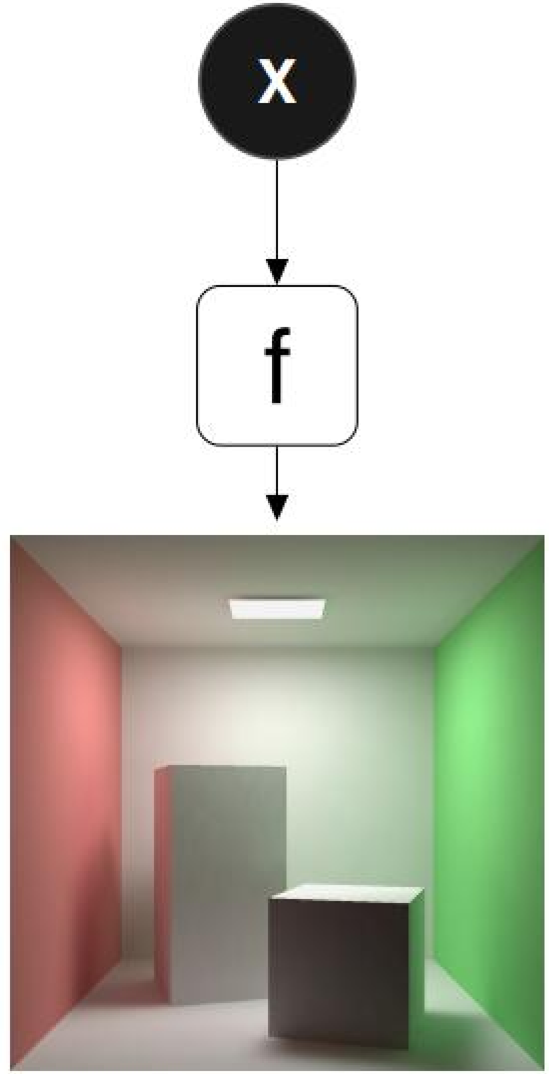
## Image-based Rendering

# Image-based Rendering

**X** constitutes:

- Geometry
- Texture
- Lighting
- Material

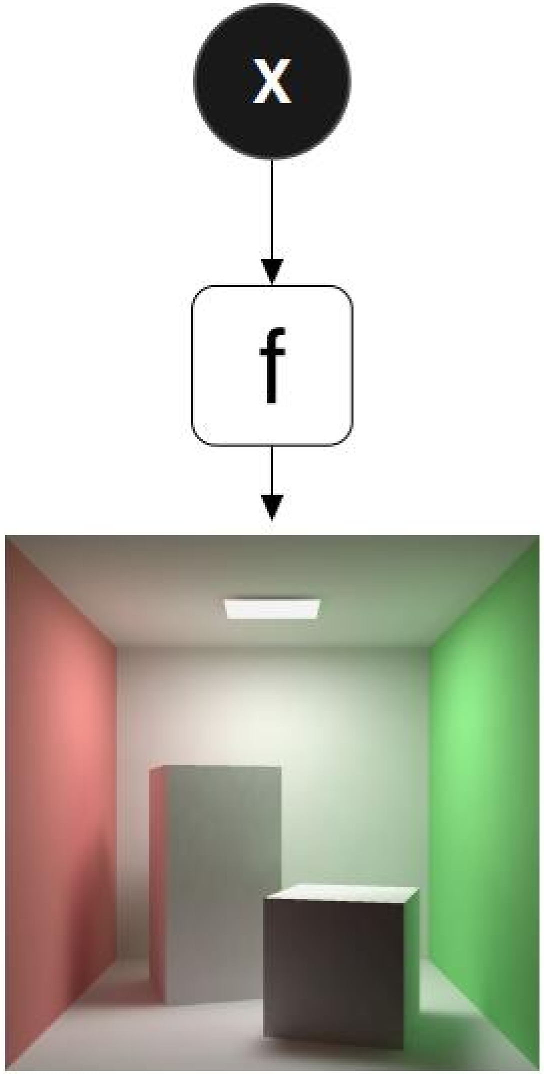
Parameterisation of the 'world'



# Image-based Rendering

How does *f(.)* manipulate **X**?
- Light
- Surface interaction
- Light transport

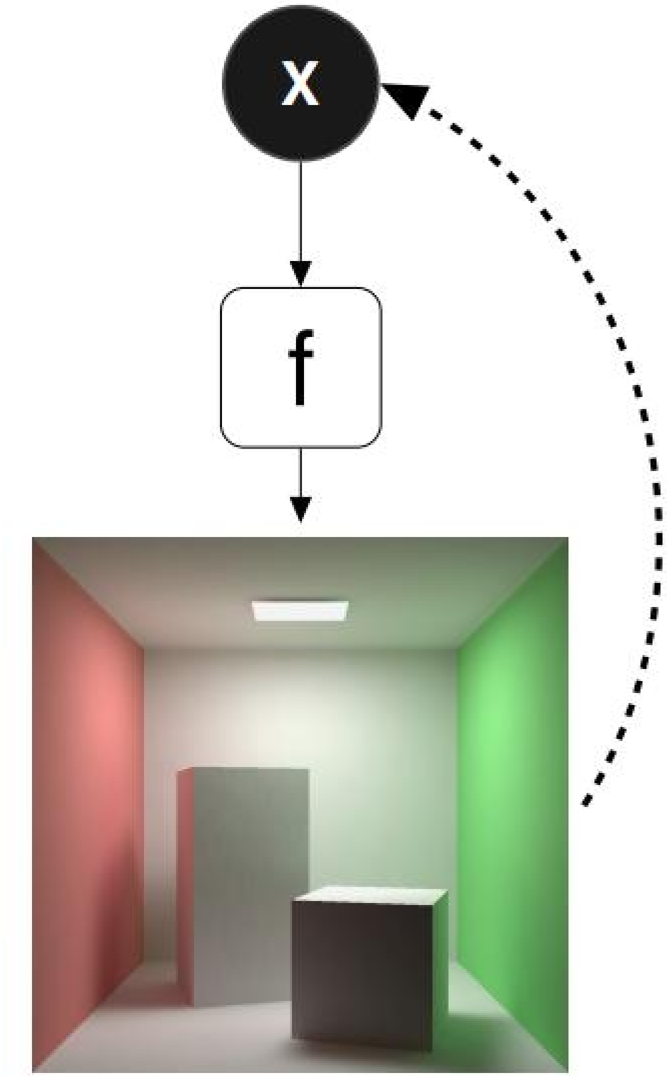
Formulate model *f(.)* through assumptions



# Image-based Rendering

Computer Vision

- Image easy to acquire
- Solve inverse problem
- What parameters have generated the image?



# Image-based Rendering

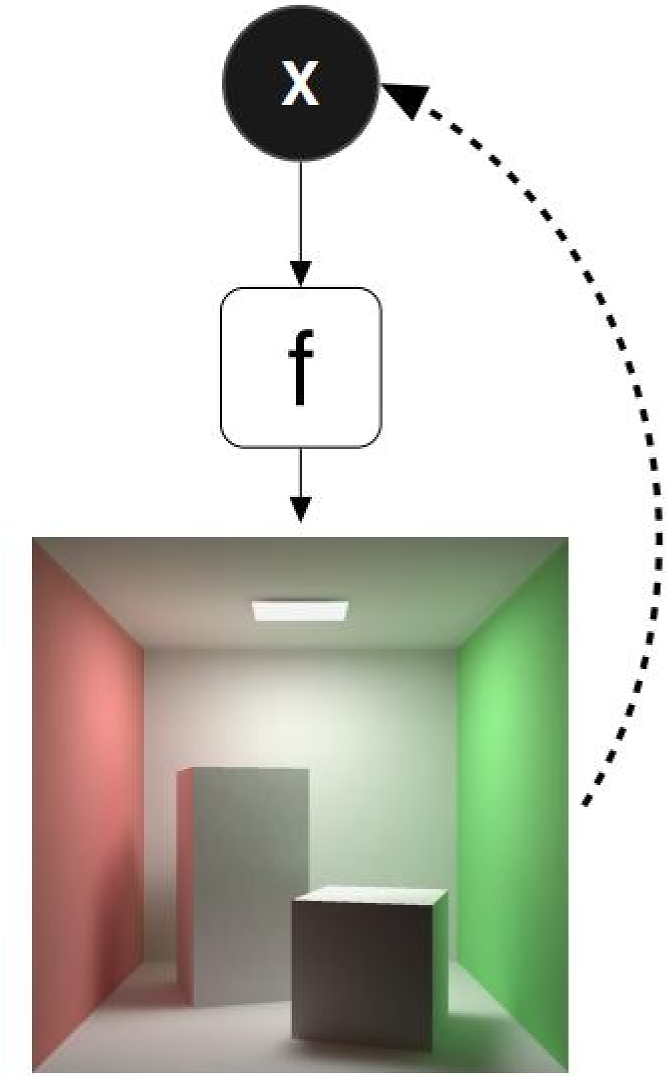
Challenge:

Given an image recover the parameters

- Texture
- Light
- Geometry

Models still valid

- $x_i = f^{-1}(y_i)$



# Image-based Rendering

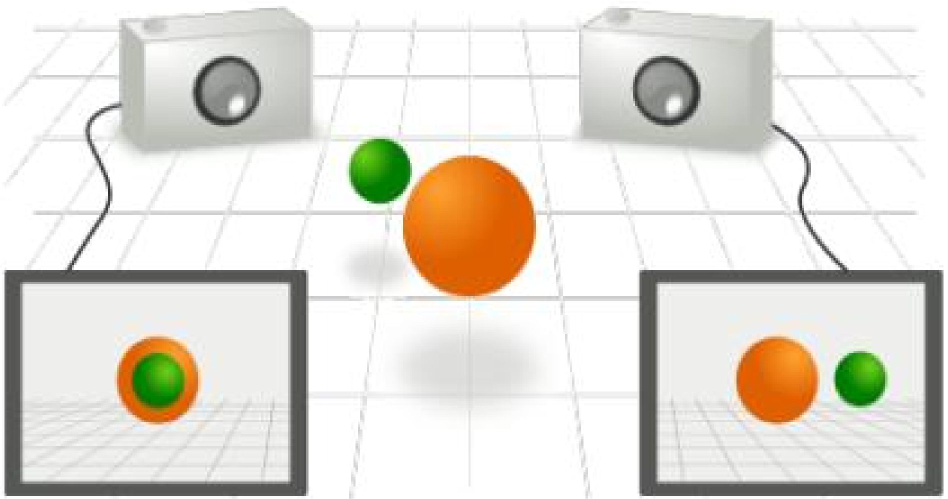
Rendering: generate images from viewpoints

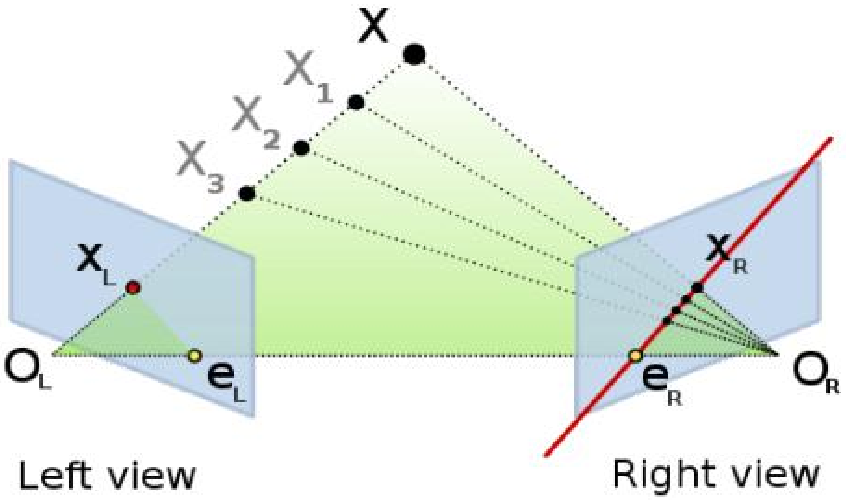
Image-based rendering: replace geometry and material attributes with real images

Most realistic image? A photograph

- Lacks flexibility
- Cannot change lighting or viewpoint
- Combine images to produce a new one

# Epipolar Geometry






- The geometry of stereo vision
- Two cameras viewing 3D scene from different positions
- Study geometric relations between 3D points and their 2D projections
- More images = more constraints

# II.

Animation

# Animation

Basis

Showing consecutive related static images one after another produces the perception of a moving image

Traditional Animation

Master artists draw certain important **key-frames** in the animation

Apprentices draw the multitude of frames in-between these key-frames

Called **tweens**

# In Practice

For computers animation:

Object has an initial configuration and a final configuration (often specified by the artist)

Computer must figure out the intermediate configurations: *interpolation*

Orientation Interpolation:

Given two key-frame orientations, figure out an intermediate orientation at a certain point between them

Possible solutions: Euler angles and rotation matrix interpolation

# #1: Euler Angles

- An Euler angle is a rotation around a single axis
- Any orientation can be specified by composing three rotations
  - Each rotation is around one of the principle axes
  - i.e. (x, y, z) – first rotate around x, then y, then z
  - Think of roll, pitch and yaw of a flight simulator
- When rotating about a single axis, is possible to interpolate a single value
  - However, for more than one axis, interpolating individual angles will not work well
  - Unpredictable intermediate rotations
  - Gimbal lock

# #2: Rotation Matrices

Interpolating between two rotation matrices does not result in a rotation matrix

- Does not preserve rigidity of angles and lengths
- This result of an interpolation of 0.5 between the identity matrix and 90 degrees around the x-axis does not produce a valid rotation matrix:

$$\text{Interpolate}\left( \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}, \begin{vmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & -1 & 0 \end{vmatrix} \right) \equiv \begin{vmatrix} 1 & 0 & 0 \\ 0 & 0.5 & 0.5 \\ 0 & -0.5 & 0.5 \end{vmatrix}$$

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# Solution

- Use *quaternion interpolation*
- Quaternions don't suffer from Gimbal lock
- Can be represented as 4 numbers instead of 9 of a 3x3 matrix
- Trivial conversion between angle/axis representation
- Interpolation between two quaternions is easy (once you know how)
- Quaternion looks like this:

  q[w,(x,y,z)]     also written q[w,v] where v = (x,y,z)

  q = w + xi + yj + zk

# Representation

- For a right-hand rotation of $\theta$ **radians** about unit vector *v*, quaternion is:

$$q = (\cos(\theta/2); \mathbf{v} \sin(\theta/2))$$

- Note how the 3 imaginary coordinates are noted as a vector
- Only **unit quaternions** represent rotations
  - Such a quaternion describes a point on the 4D unit hyper-sphere
- Important note: q and –q represent the **exact same** orientation
- Different methods for doing quaternion interpolation:

LERP, SLERP (Spherical linear interpolation)

# In Practice

- Not always the best choice
  - Quaternions are (as you will have noticed) hard to visualise and think about
  - If another method will do and is simpler, it will be a more appropriate choice
- But…
  - Extremely useful in many situations where other representations are awkward
  - Easy to use in your own programs once you have a quaternion class
  - See GLM library

# III.

Where to next?

# Shaders and GPU Programming

Advice: learn Fixed Function Pipeline first

Shading languages include: HLSL, GLSL, CG

```
#version 400
layout( triangles, equal_spacing)  in;

void main( )
{
        vec4 p0 = gl_in[0].gl_Position;
        vec4 p1 = gl_in[1].gl_Position;
        vec4 p2 = gl_in[2].gl_Position;

        vec3 p = gl_TessCoord.xyz;

        gl_Position = p0*p.x + p1*p.y + p2*p.z;
}
```

Simple GLSL shader example

USC/Nvidia Face Works tech demo

# Middleware

Relieve the tedium of recoding everything

Already used in labs: *SDL* and *GLM*

Many other libraries and engines available

Some examples:

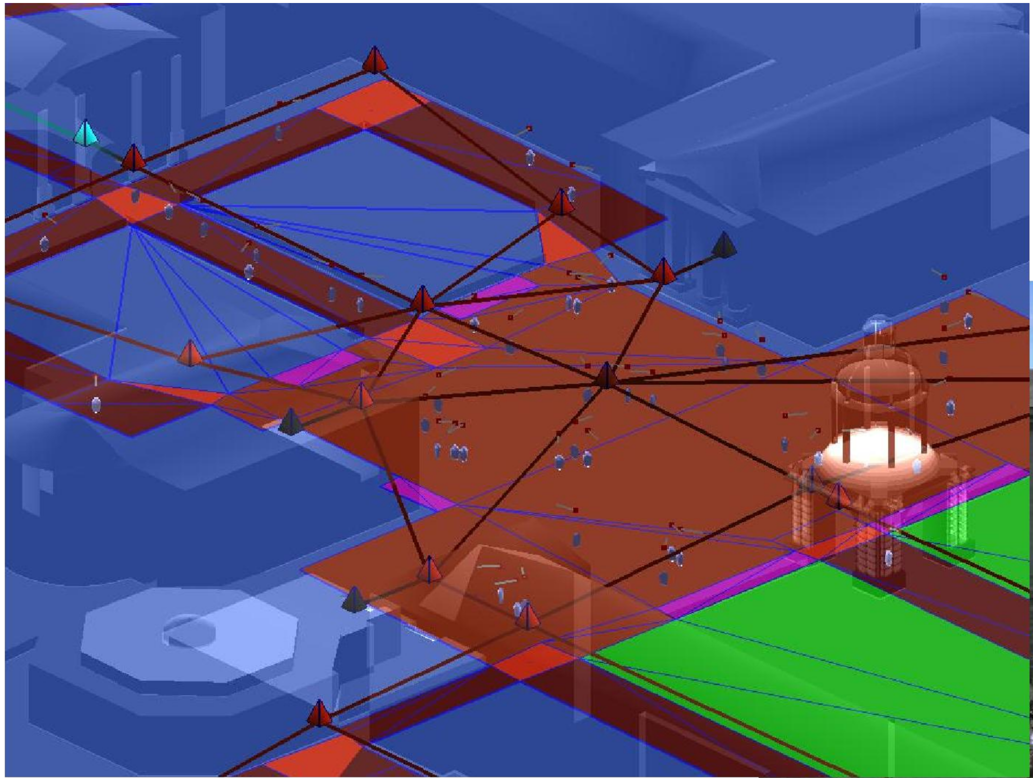
- GLEW: http://glew.sourceforge.net/
- Assimp: http://assimp.sourceforge.net/
- ODE: http://www.ode.org/
- FMOD: http://www.fmod.org
- RakNet: http://www.jenkinssoftware.com/
- OGRE: http://www.ogre3d.org/
- Torque 3D: http://www.garagegames.com/

# Crowds

*Aggregate Dynamics for Dense Crowd Simulation*, Narain et al., UNC, 2010

Metropolis Project, GV2, Trinity College Dublin

# Toolchains

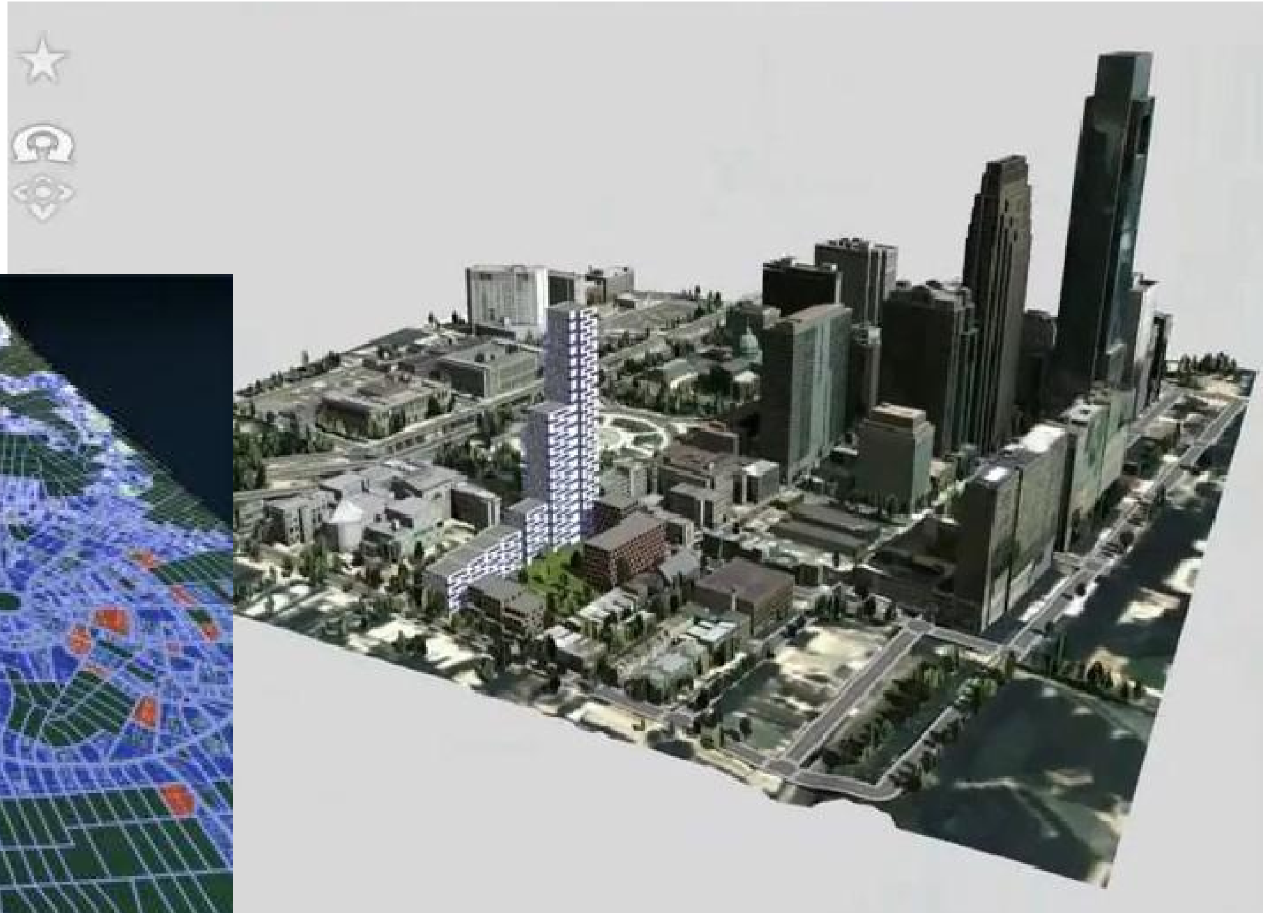


<- Environment mark-up tool (*Metroped*)

Metropolis Project, GV2, Trinity College Dublin

Results transferred into final rendering client ->

# Procedural Cities

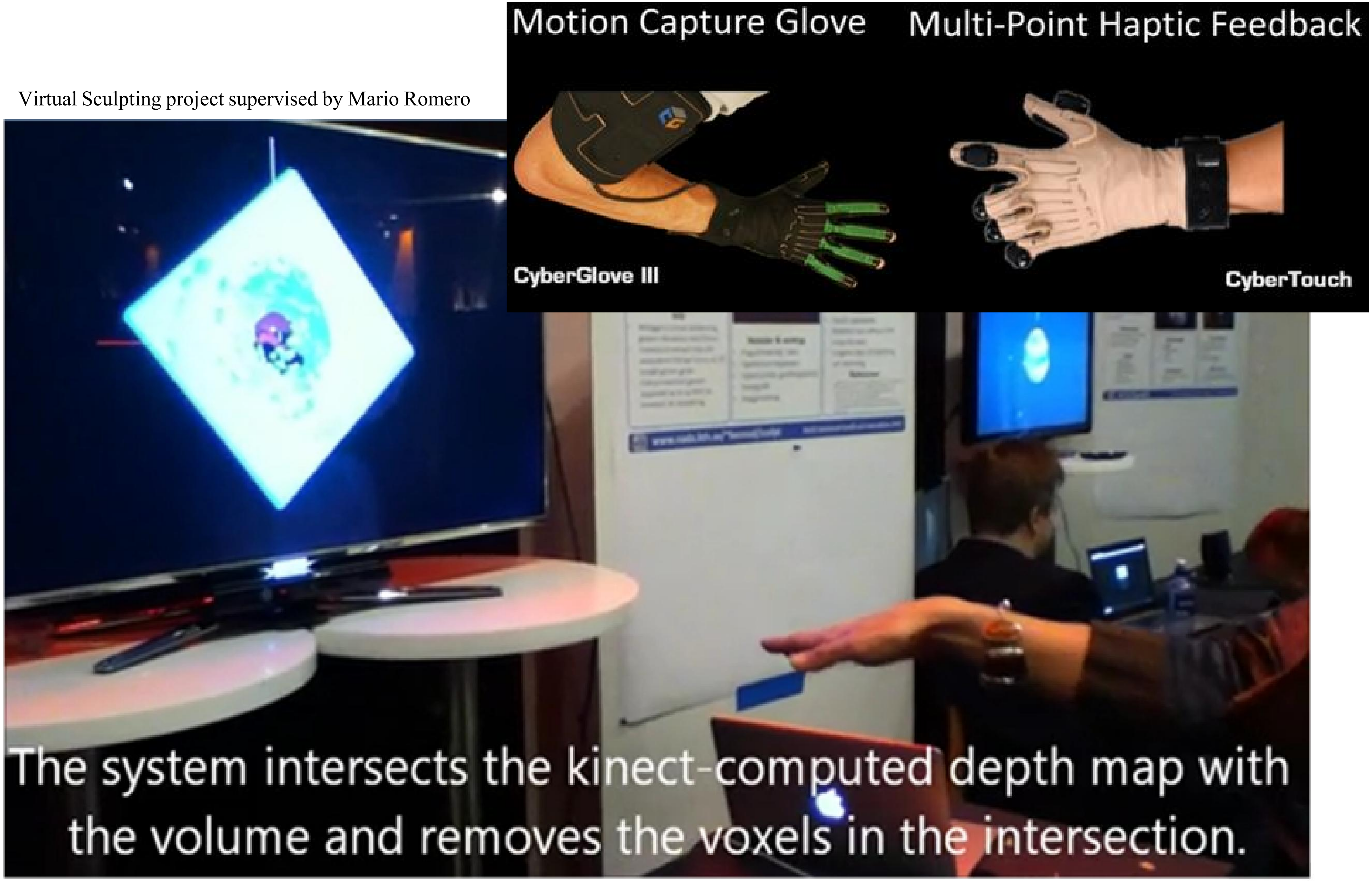


ESRI City Engine


Introversion Procedural City Generator

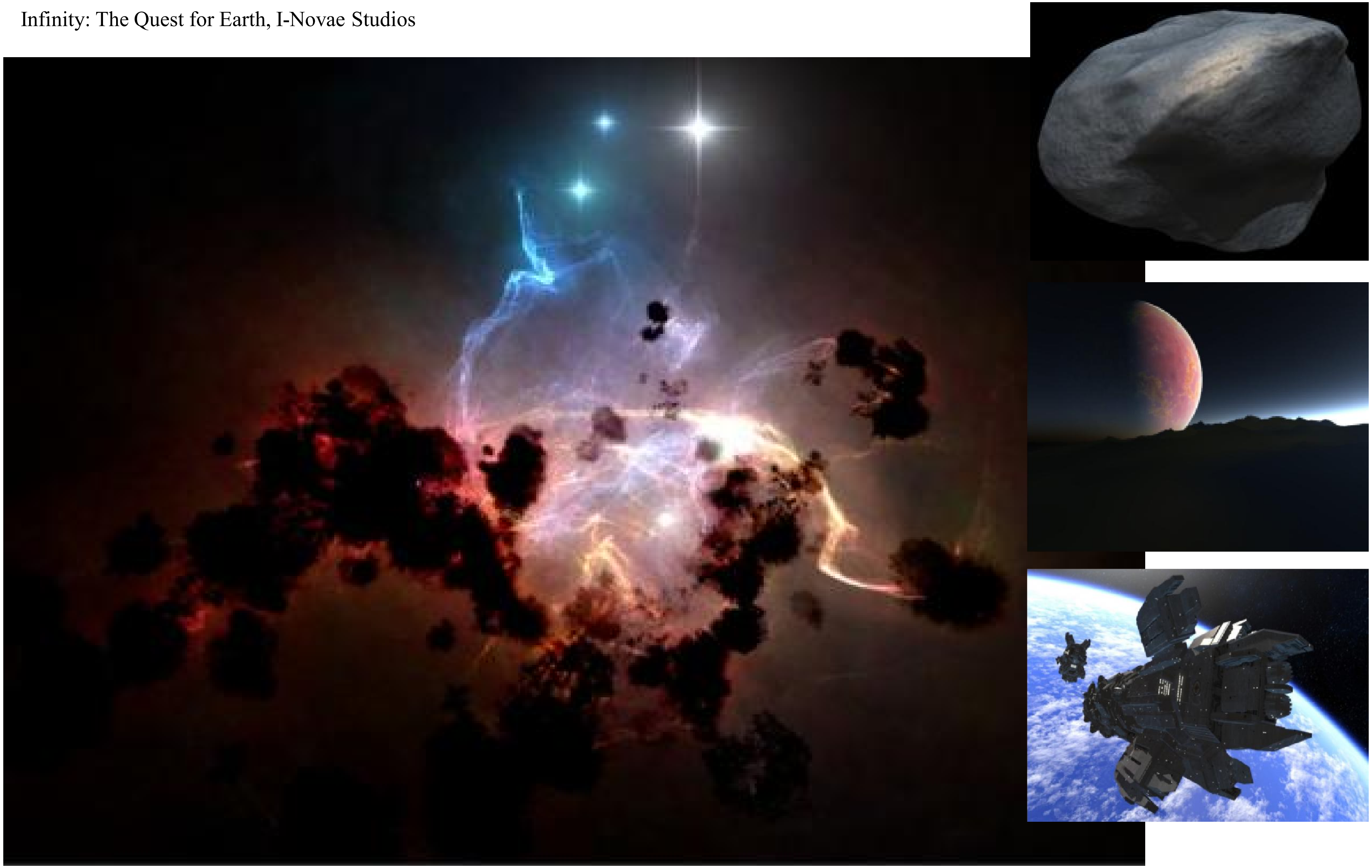
# HCI and Interfaces

Virtual Sculpting project supervised by Mario Romero



# Real-time Procedural Universe

Infinity: The Quest for Earth, I-Novae Studios



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# Links

http://www.pandromeda.com/

MojoWorld: planet synthesis

Anderson and Peters, No More Reinventing the Virtual Wheel: Middleware for Computer. Games and Interactive Computer Graphics, Eurographics 2010

Paper on middleware for games and graphics

# Reminders

- You should be working on Lab 3
- Labs due on 8th May
  - Bilda DGI15 DH2323 lab submission is now open

- Next lab help session:
  - More information to follow…

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# Next lecture

*Bezier Curves, Splines and Surfaces*

- Guest speaker: Prof. Tino Weinkauf
- This Wednesday ($6^{th}$ May), B2
- 15:00 – 17:00