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Computer Graphics

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COMP3421/9415
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2021 Term 3 Lecture 8

What did we learn last lecture?

Scene Graphs

- Organisation for complicated scenes and hierarchical objects

Depth Testing

- Rendering things in the right order
- Seeing only what's in front

Blending

- Also seeing what's behind something if it's transparent!

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What are we covering today?

Parametric Equations

- Linear Interpolation
- Using parameters to control movement and curves
- Also using time as the driver

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Linear Interpolation

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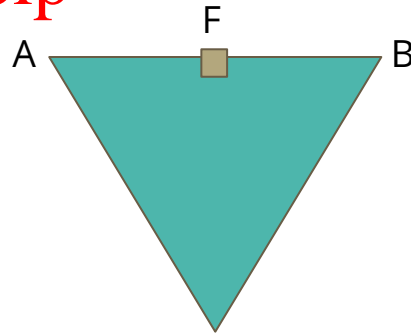
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Maths inside Fragment Shaders

How do we choose a texture coordinate or colour in between two vertices?

- Vertices A and B have texture coordinates A_T and B_T
- What's the texture coord of my fragment F?
- If it's halfway between them.
 - $F_T = A_T * 0.5 + B_T * 0.5$
 - This means both A and B have 50% influence over the texture coordinate



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Linear Interpolation

This works for all points between the two vertices

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- Not just the halfway point

- If F is at A:

- $F_T = A_T * 1.0 + B_T * 0.0$

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- Or at B:

- $F_T = A_T * 0.0 + B_T * 1.0$

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- You can see a pattern forming:

- $F_T = A_T * (1.0 - t) + B_T * t$

- If we use a parameter, t , we can represent all the possible values between the two points

What can we do with this technique?

Finding points between two points

- Moving t between 0 and 1 can give us any point between A and B
- This gives us a very simple way of moving between vertices
- We can describe a line or path by only using the end points
- We can also do a smooth transition between properties like colours or texture coordinates

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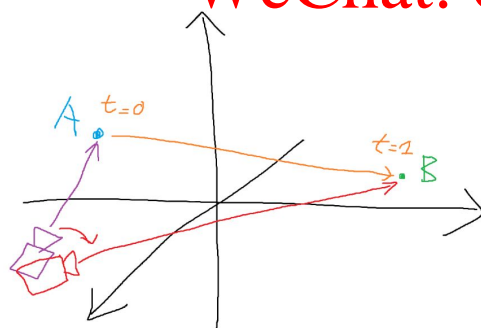
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Using Time as a Parameter

Moving in time

- If we change our t based on Δ time, we can animate movement between positions
- We can apply an interpolation to a coordinate or vector, so we could do something like a smooth Δ time based pan of a camera



$$t = \text{elapsed time} / 5\text{sec}$$

Change the camera's "target" by linear interpolation and recalculate lookAt each frame. In 5 seconds we'll pan from A to B.

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Parametric Equations

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Straight Lines Only?

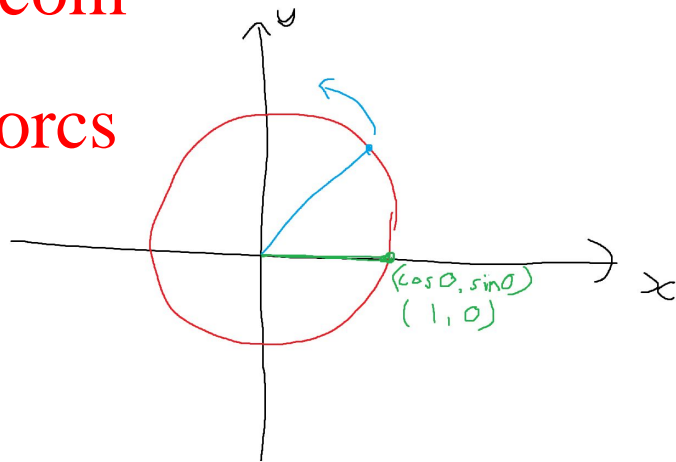
Let's add more interesting paths

- Linear Interpolation is straight lines between two points or values
- But the idea of parametric equations can do way more than that
- Try this one:
 - $x = \cos(t)$, $y = \sin(t)$
 - This one even works for any value of t .

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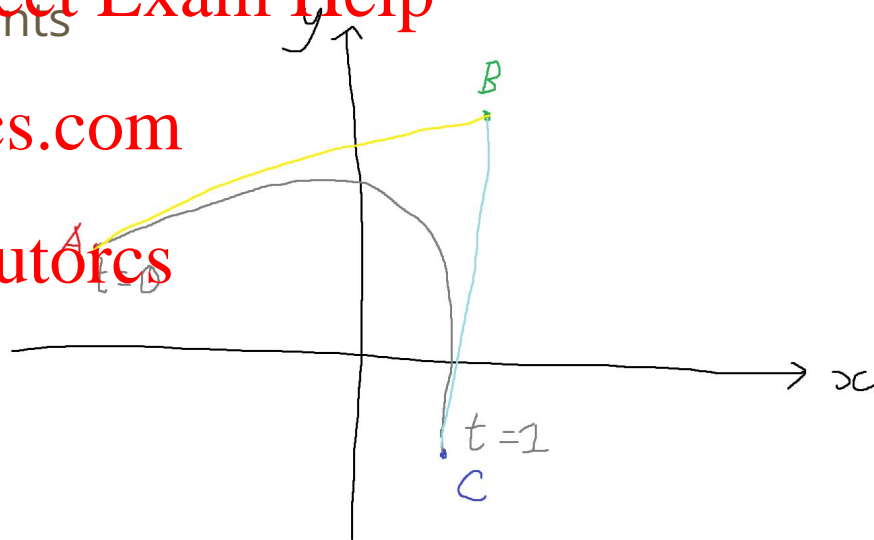
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Control Points

Points that influence a line based on a parameter

- We've seen a single line with two points
- What about more points?
- Let's look at Bezier Curves
- They're parametric
- And use multiple points



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Bezier Curves/Splines

Makes use of Linear Interpolation

- If we have multiple points, we'll linearly interpolate at multiple levels
- Each line we draw is a tangent to the curve

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Different types of Bezier Curves/Splines

Each curve has a parametric formula

- Two points (Linear Interpolation)

- $P = (1-t)P_1 + tP_2$

- Three points (Quadratic Curve)

- $P = (1-t)^2P_1 + 2(1-t)tP_2 + t^2P_3$

- Four points (most commonly used in Graphics)

- $P = (1-t)^3P_1 + 3(1-t)^2tP_2 + 3(1-t)t^2P_3 + t^3P_4$

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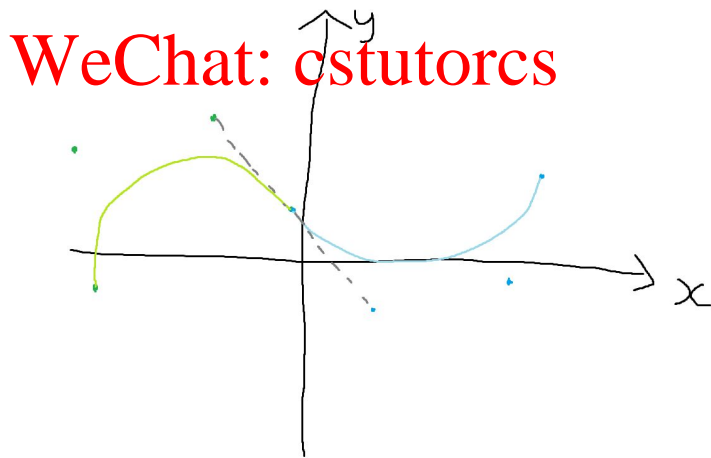
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Useful Properties

Bezier curves ...

- Tangents based on control points
 - At either end, the two closest control points form a tangent
- Join multiple curves together smoothly using colinear control points



More Advanced Curves and Splines

We can join them together, but . . .

- While the gradient will be equal at the join
- No guarantees about the second derivative

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Why is that an issue?

- If we're using this curve as a path to move on, the speed won't be the same at the join
- Check out B-Splines if you want to know more about possible solutions

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Splines in Graphics

- Polygon Rendering works in straight lines
 - Want a lot of points spaced out along a curve?
 - A parametric curve allows us to create an arbitrary number of points
 - We can draw our lines between those points to approximate the curve
- If we are moving an object along a curve
 - We can reach arbitrary positions using our parameter (link delta time to the parameter)
 - If we need a tangent, we can do a simple approximation by creating another nearby point
- Easy to modify
 - Just move control points around to change the nature of the curve
- A downside: Can't quite control size and speed
 - You can't necessarily move along a spline at a fixed speed
 - Parameter based movement is based on how far apart control points are

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Break Time

Ed Catmull's interesting career

- Invented Texture Mapping (1974)
- Invented the Catmull Rom Spline (1974)
- Used this and similar techniques in Keyframe Animation (1970s)
- Ended up at Industrial Light and Magic (owned by George Lucas) (1979)
- Steve Jobs buys Lucasfilm digital division and creates Pixar (1986)
- Ed Catmull was at one point President of Disney and Pixar



Image credit: Jeff Heusser (VES Awards 2010)

Using Splines

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Hello Teapot our old friend

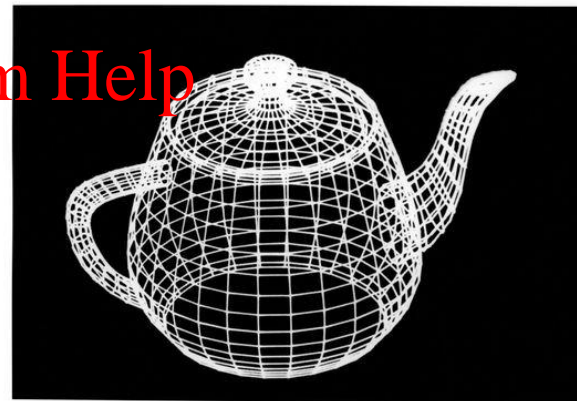
How would we create this object?

- Several tricks in use here!
- We have curves, but how are we creating surfaces?
- We can create something like the teapot with just some simple equations and transform matrices

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University of Utah
Computer Science

Image credit: School of Computing, University of Utah

Surfaces of Revolution

The body of the teapot

- We can create a curve (side of the pot)
- Translate that curve away from (0,0,0)
- Create a series of points along that curve (using values of t)
- Then we can rotate the curve and its points around the Y axis
- At different rotation angles (the Utah teapot has about 30) we can create vertices
- Make triangles from those vertices and build up buffers

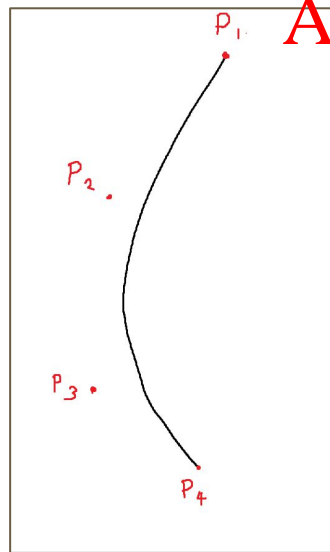
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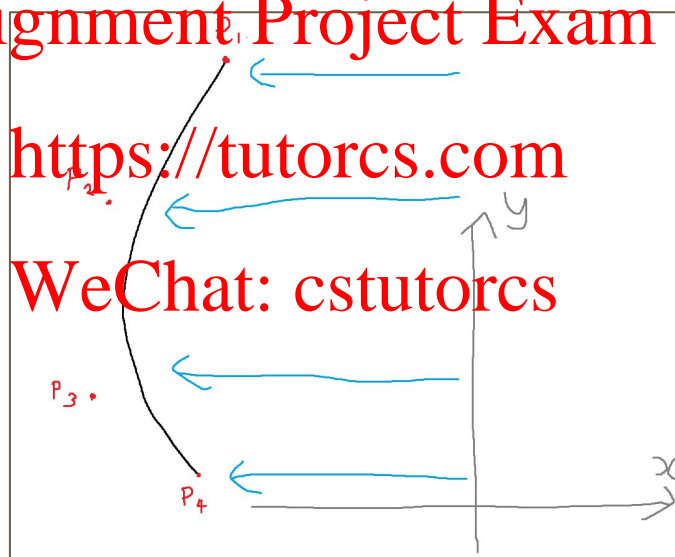
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A Surface of Revolution

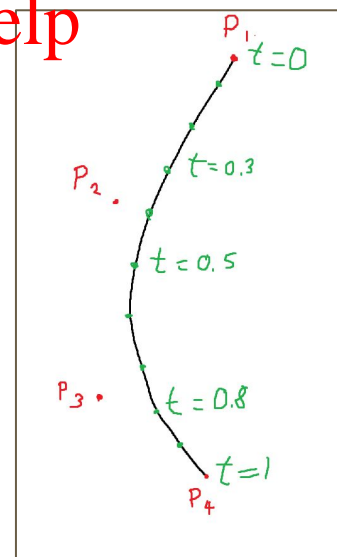
In Images



Create a curve



Translate away from y axis



Choose t values
for points

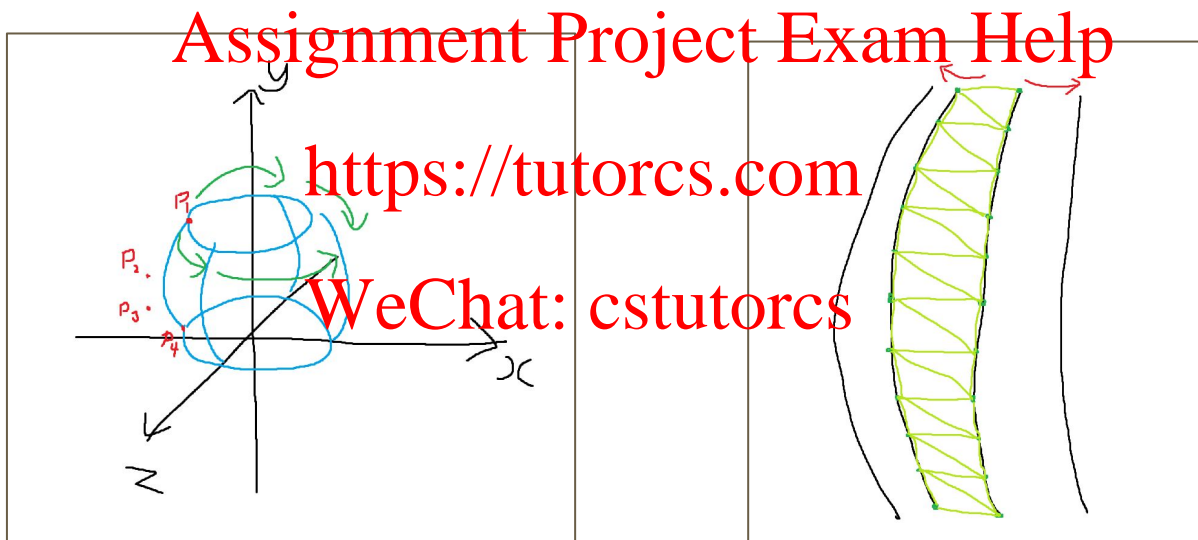
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A Surface of Revolution

In Images (continued)



Rotate the curve to different orientations around the y axis

Between two of the close curves, create vertices and triangles

Extrusion

Dragging a shape through space, the handle of the teapot

- We can create a curve (the centre of the handle)
- Translate that curve into the correct position at the back of the teapot
- Create a series of points along that curve (using values of t)
- Create a circle (the thickness of the handle)
- Place the circle at each those points
- Use the circle to create vertices

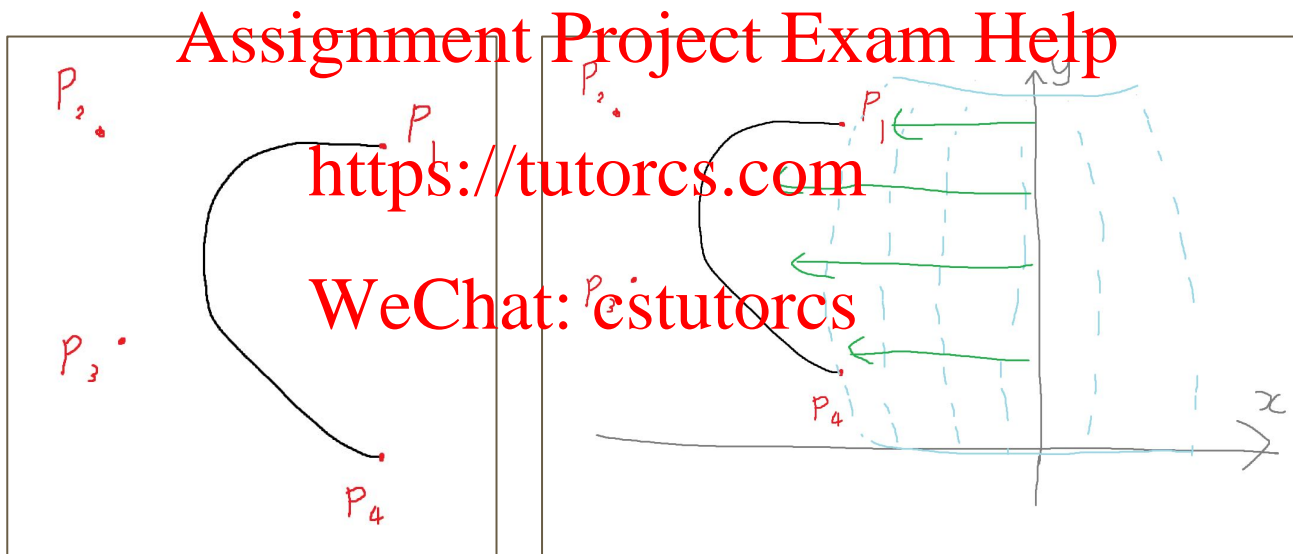
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Extrusion

In Images

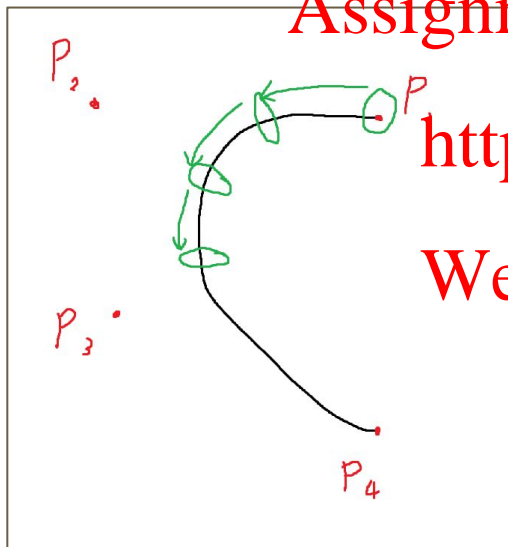


Create a curve

Translate the handle into position

Extrusion

In Images (continued)



Create a circle and place it at different points along the curve



Create vertices around the circles and create triangles between them

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Other parts

The lid

- Another surface of revolution, just a slightly more complex curve

The spout

- This gets harder
- An extrusion that is scaled based on distance from the pot?

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Techniques for 3D Object Creation

Digital Artists might use a lot of these

- Rotation and extrusion are definitely used
- And simple things like scale, rotate and translate!
- Artists will not usually be expected to be computer scientists and mathematicians
 - So there are tools like Maya and Blender to hide the details
- There's also raw sculpting though
 - Digital Clay! (Zbrush uses this kind of technique)

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Let's guess how some things were made

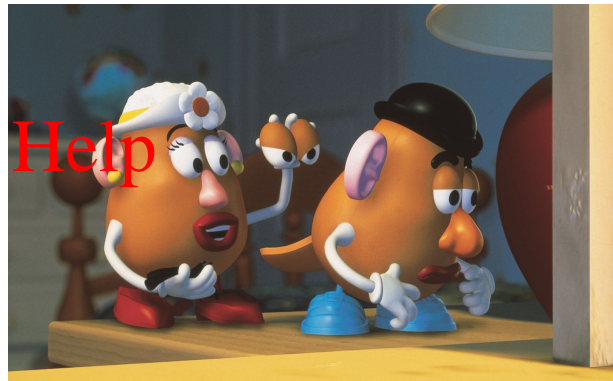
Toy Story is a classic that's historically very important!

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- Potato heads
 - Obvious separate objects with scene graph attachments
 - Some simple rotational volumes
- Buzz Lightyear
 - Transparency nightmare!
 - Very simple scene graph with rigid components
- Woody
 - Squishy bits . . . we'll talk about these later!



Images credit: Disney Pixar

What did we learn today?

Parametric Maths and its applications

- Linear Interpolation
- Parametric Curves/Splines
- Using Bezier Curves in 3D
- A small look at how 3D Artists create some game/film assets

Homework

- Watch Toy Story and Monsters, Inc. (Two Pixar films 6 years apart)
- See if you can guess how some things were made and also the technical advancements between the two movies

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