

Edwin Catmull

By William Vida



Introduction

- ▶ Edwin Catmull is an American computer scientist known for his great contributions towards 3D computer graphics.
- ▶ Catmull was one of the founders of Pixar Animation Studios.
- ▶ Catmull was one of the developers of Pixar's RenderMan rendering software.
- ▶ He was awarded the 2019 A.M. Turing award along with Pat Hanrahan for their "fundamental contributions to 3-D computer graphics, and the revolutionary impact of these techniques on computer-generated imagery (CGI) in filmmaking and other applications".

Examples of Catmull's Contributions

- ▶ Image compositing.
- ▶ Motion blur.
- ▶ Subdivision surfaces.
- ▶ Cloth simulation and rendering techniques.
- ▶ Texture mapping.
- ▶ Z-buffer.
- ▶ Bicubic patches.

A Computer Animated Hand

- ▶ A Computer Animated Hand is a 1972 computer-animated short film produced by Edwin Catmull and Fred Parke as a graduate student project.
- ▶ Catmull animated a human hand and it was one of the earliest examples of 3D computer animation.
- ▶ It is one minute long and it shows an animated hand turning, opening, closing, pointing and flexing its fingers.
- ▶ It was a revolutionary invention and Catmull worked out concepts that become the foundation for computer graphics following its completion.
- ▶ In 2011, it was introduced into the National Film Registry of the United States.

A Computer Animated Hand



RenderMan

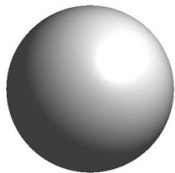
- ▶ RenderMan is a piece of software that Pixar uses to create 3D animations. RenderMan has been used to create movies such as Toy Story, Independence Day, Monsters, Inc. and The Lion King.
- ▶ RenderMan incorporates some of Catmull's inventions such as z-buffering and subdivision surface algorithms.

Texture Mapping

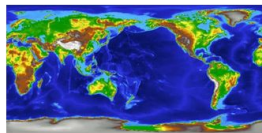
- ▶ Catmull first described the process of texture mapping in his 1974 PhD thesis "A subdivision algorithm for computer display of curved surfaces".
- ▶ Texture mapping is a process in which a 2D surface is wrapped around a 3D object.
- ▶ Before Catmull's discovery, objects could only be set to one specific colour and adding detail became a much longer process.
- ▶ Catmull's original technique for texture mapping is referred to as diffuse mapping.

Texture Mapping

Texture Mapping



Object



Texture



Texture
Mapped
Object

Z-Buffering

- ▶ Catmull is credited with the invention of the z-buffering concept.
- ▶ Z-buffering is a technique used in 3D computer graphics to determine what parts of an object are visible in a scene.
- ▶ The z-buffering algorithm uses the graphics processor to store each pixel's z-axis value in a special memory region called the Z-buffer. Different objects might have the same values for their x and y-coordinates, but have different values for their z-coordinates. The object with the lowest z-coordinate value is positioned in front of the other objects and that is the one that will be seen.

Z-Buffering

Pseudocode of the algorithm:

First of all, initialize the depth of each pixel.

i.e, $d(i, j) = \text{infinite (max length)}$

Initialize the colour value for each pixel

as $c(i, j) = \text{background colour}$

for each polygon, do the following steps:

for (each pixel in polygon's projection)

{

 find depth i.e, z of polygon

 at (x, y) corresponding to pixel (i, j)

 if $(z < d(i, j))$

 {

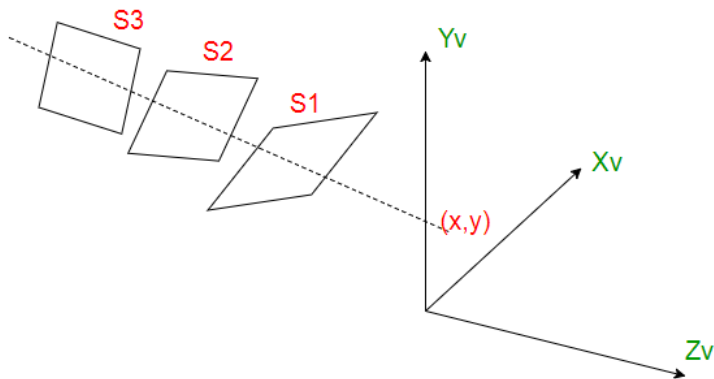
$d(i, j) = z;$

$c(i, j) = \text{colour};$

 }

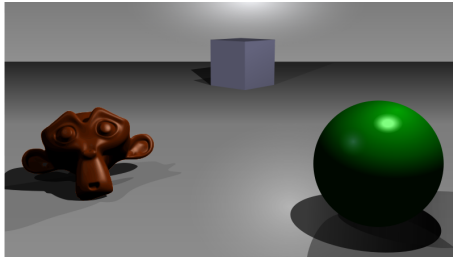
}

Z-Buffering

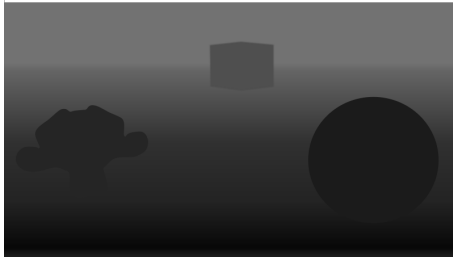


After the algorithm checks S1, S2 and S3, S1 will be visible from the viewpoint.

Z-Buffering



A simple three-dimensional scene

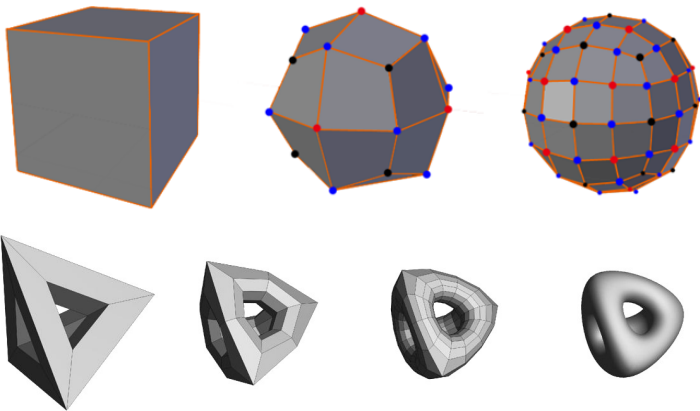


Z-buffer representation

Subdivision Surface

- ▶ Edwin Catmull and Jim Clark came up with the Catmull–Clark algorithm in 1978.
- ▶ The Catmull-Clark subdivision is a technique for smoothing the surface of a 3D polygon mesh by dividing the polygons of the surface into smaller polygons and repositioning the previous vertices based on vertices close to it. This approach takes each polygon found in the mesh and divides the polygon into quadrilaterals (four-sided polygons) and then, based on the averages, constructs new vertices. After, it changes the original polygon's previous vertices depending on the surrounding area.
- ▶ It is a fast and effective algorithm.

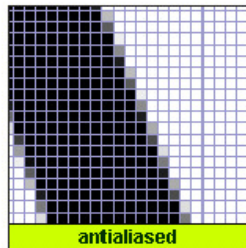
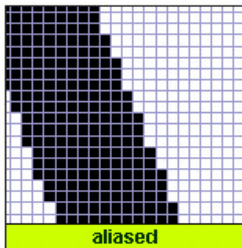
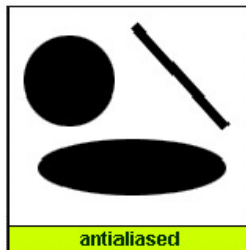
Subdivision Surface



Spatial Anti-Aliasing

- ▶ In 1978, Catmull released his thesis on spatial anti-aliasing titled "A hidden-surface algorithm with anti-aliasing".
- ▶ Aliasing happens when smooth and curved lines become rasterised and anti-aliasing is the process of the smoothening of the jagged edges.
- ▶ Anti-aliasing smoothes the pixels by filling in the jagged edges with shadowing pixels.

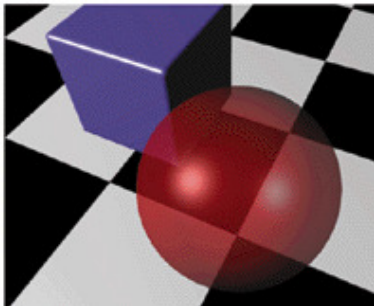
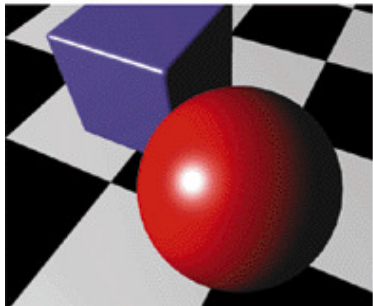
Spatial Anti-Aliasing



Alpha Channel

- ▶ Edwin Catmull and Alvy Ray Smith invented the concept of the alpha channel in RGBA.
- ▶ The alpha channel is used to make it seem that an image is partially to fully transparent compared to another image.
- ▶ Before the alpha channel, an image had to be rendered with different backgrounds which was a slow procedure. They came up with the idea when Catmull said that it would be easier to render the opacity with the colour information in a file for each pixel. Then the file could be made without rerendering over different backgrounds.

Alpha Channel



Motion Blur

- ▶ Motion blur is the streaking or tails of an object or objects when a picture or video is taken.
- ▶ Catmull wanted to recreate this in animations to add realism to animation scenes. Catmull said that solving this was the "single hardest problem we had".
- ▶ Rob Cook suggested looking at 16 pixel points at $1/60$ of second (which is the speed at which a film camera shutter opens and closes). Then, several different objects will move over that pixel. Tom Porter's answer was to get the colour of each of those 16 points at that moment. This allowed him to assign each pixel an average and this allowed a blurring effect to be reproduced in animations.
- ▶ Before this discovery, animation objects would move in a way where it seemed they were teleporting each time they moved.

Motion Blur



Awards

- ▶ Catmull has been awarded 5 Academy Awards, an IEEE John von Neumann Medal, the 2019 Turing Award, a Scientific and Engineering Award, an ACM SIGGRAPH Steven A. Coons Award and a Gordon E. Sawyer Award.

References

Z-Buffering

Projections and Z-buffers

Z-Buffer or Depth-Buffer method

3-DIMENSIONAL SMOOTHING: CATMULL-CLARK
SUBDIVISION

Proposed workflow for UV mapping and texture painting

Ed Catmull

2019 Turing Award

Edwin Catmull

Computer Graphics — Antialiasing

3dfx T-Buffer Technology Overview

EDWIN CATMULL

The Alpha Channel

Alpha and the History of Digital Compositing

ED CATMULL

And the Oscar Goes To...

Paving the Way