REPRESENTATION IN COMPUTER GRAPHICS

A high-school introductory course
 Presented by Valentina Shin, Adriana Shulz, and Zoya Bylinskii
Presented by Valentina Shin

ICEBREAKER ACTIVITY
Introduction Activity

How to draw Mike Wazowski
Learning objectives

Through this activity, we would like students to:

• Think about different ways of representing a shape
• Learn that the choice of representation affects accuracy of expression
• Experience what it is like to program or think like a computer.
Instruction

• Students pair up as teams (2 students per team).
• In each team, student A will get a picture of Mike Wazowski on top of a grid. Student B will get an empty grid. Each team gets one type of primitive (shape, color, or line) with which to express the picture. Student A gives instructions to student B about how to use the primitives to draw the picture.
• In the end, we will bring up the final pictures of students, place them on the board. Students can compare how different primitives express the same picture in different ways.
Instruction (Colors A)

You have a picture of Mike Wazowski. Your partner has an empty grid, identical to the grid that you have. In addition to the grid your partner has three colors (green, blue, black). Your task is to help your partner draw Mike Wazowski as well as possible. There are rules to keep in mind!

1. You CANNOT show your partner the picture.

2. You can ONLY say the following type of sentence:
   “Color A1 with black.”
   “Color B3 with green.”
   “Color U12 to U15 with black.”

... Please keep track of how many cells you color in total.
Instruction (Colors B)

You have an empty grid and three colors (green, blue, black). In addition to the identical grid, your partner has a picture on top of it. Your task is to follow your partner’s instructions to draw a picture. There are 2 rules to keep in mind!

1. You CANNOT look at your partner’s picture.

2. Your partner can ONLY say the following type of sentence:
   “Color A1 with black.”
   “Color B3 with green.”
   “Color U12 to U15 with black.”

   ...

Please keep track of how many cells you color in total.
Instruction (Shape A)

You have a picture of Mike Wazowski. Your partner has an empty grid, identical to the grid that you have. In addition to the grid your partner has a set of shapes and three colors (black, green and blue). Your task is to help your partner draw Mike Wazowski as well as possible. There are 2 rules to keep in mind!

1. You CANNOT show your partner the picture.

2. You can ONLY say the following type of sentence:
   “Place the (center of shape 1) at (A1) and color it (green).”
   “Place the (left-top corner) of (shape 7) at (A2) and color it (blue).”
   “Place the (top of shape 13) at (D14) and color it (black).”

Please keep track of how many polygons you use in total.
Instruction (Shape B)

You have an empty grid, a set of shapes and three colors (black, blue and green). In addition to the grid, your partner has a picture on top of it. Your task is to follow your partnerʼs instructions to draw a picture. There are 2 rules to keep in mind!

1. You CANNOT look at your partner the picture.
2. Your partner can ONLY say the following type of sentence:
   “Place the (center of shape 1) at (A1) and color it (green).”
   “Place the (left-top corner) of (shape 7) at (A2) and color it (blue).”
   “Place the (top of shape 13) at (D14) and color it (black).”

...  

Please keep track of how many polygons you use in total.
Instruction (Lines A)

You have a picture of Mike Wazowski. Your partner has an empty grid, identical to the grid that you have. In addition to the grid your partner has a ruler to draw straight lines. Your task is to help your partner draw Mike Wazowski as well as possible in the next 10 minutes. There are 2 rules to keep in mind!

1. You CANNOT show your partner the picture.
2. You can ONLY say the following type of sentence:
   “Draw a straight line from the (A1) to (B2).”
   “Draw a straight line from (A3) to (A8).”
   “Draw a straight line from (B4) to (C10).”
   ...

Please keep track of how many line segments you use in total.
Instruction (Lines B)

You have an empty grid and a ruler to draw straight lines. In addition to the grid, your partner has a picture on top of it. Your task is to follow your partner’s instructions to draw a picture in the next 10 minutes. **There are 2 rules to keep in mind!**

1. You **CANNOT** look at your partner the picture.

2. Your partner can **ONLY** say the following type of sentence:
   
   “Draw a straight line from the (A1) to (B2).”
   “Draw a straight line from (A3) to (A8).”
   “Draw a straight line from (B4) to (C10).”

   ...

*Please keep track of how many line segments you use in total.*
After the activity...

- Did you have a particular strategy?
- What did you focus on? Accuracy? Efficiency?
- What do you notice with the different representations?
- What was hard, and what was easy?
INTRODUCTION

Presented by Zoya Bylinskii
who’s been to MOS recently?

Watch this intro: https://youtu.be/3lu1Z0h1i1Y?t=47

Learn more about the exhibit

http://www.mos.org/exhibits/the-science-behind-pixar
Every Pixar movie goes through these steps, but the process is not entirely linear.

START

Rendering

Story & Art

Lighting

Modeling

Simulation

Rigging

Animation

Surfaces

Sets & Cameras

on exhibit at the Boston Museum of Science
SKETCHING

https://www.fxguide.com/featured/inside-out-rendering/

MODELING


https://www.fxguide.com/featured/inside-out-rendering/
Learn more about behind the scenes of inside-out


Learn more about creating 3D characters

https://www.fxguide.com/featured/inside-out-rendering/
FINISHED PRODUCT

Every Pixar movie goes through these steps, but the process is not entirely linear.

on exhibit at the Boston Museum of Science today!
The math behind the magic
A new way to look at the world

https://www.pinterest.com/jessicamegan8/minions/
Explore some 3D models of Pixar cars

See more examples of rigging faces for emotion simulation.

Modeling

- Mathematical representation of 2D and 3D shapes, objects, and characters
- A model is composed of primitives
From the ice-breaker
Modeling Mike

• How did you represent Mike?
• What were your primitives?
REPRESENTING 3D SHAPES (I)
-VOXELS, TRIANGLE MESH, CSG, HEIGHT FIELD

Presented by Adriana Schulz
Representing 3D Shapes
Virtual World
Virtual World

MODELING
Modeling is DESCRIBING the shape of objects to the computer
Modeling is DESCRIBING the shape of objects to the computer.
3D Model
3D Shape
3D Geometry
Representation

Many ways to do this!
P = (x_0, y_0)
0.345678910111121313....
\[ P = (x_0, y_0) \]
Discretization
Digital Pictures

Picture

Color for every element
Digital Pictures

Picture

Color for every element
Digital Pictures

Picture → PIXELS → Color for every element
What about 3D?
What about 3D?
Volumetric Grid
3D Geometry

Volume

VOXELS

Information for every element
3D Printing
Voxel Grid Representation

• Primitive: voxel

• Recipe: material to each voxel
One down...
but let’s keep investigating!
Back to 2D

PIXELS
Back to 2D
The Resolution Issue

20X20 Grid

50X50 Grid

100X100 Grid
The Resolution Issue in 3D

In 2D: \( NXN \) \( (N^2) \)
In 3D: \( NXNXN \) \( (N^3) \)
# The Resolution Issue in 3D

In 2D: \( NXN \) \( (N^2) \)

In 3D: \( NXNXN \) \( (N^3) \)

<table>
<thead>
<tr>
<th>( N )</th>
<th>Pixels</th>
<th>Voxels</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>100</td>
<td>1,000</td>
</tr>
<tr>
<td>100</td>
<td>10,000</td>
<td>1,000,000</td>
</tr>
</tbody>
</table>

This does not scale well!!! 😞
Think again in 2D
Think again in 2D

Instead of describing the area!

We can describe the boundary
Curves
Discretization
Curves
Surfaces
Surfaces
What is a Mesh?!?!?!

Triangle Soup!
Mesh Representation

• Primitive: triangle

• Recipe: list of triangles
Let’s open some up!
Two down...
ready for one more?
The third group of the activity
Simple Shapes

Math Formula!

$P_0 = (x_0, y_0, z_0)$
How would you present this shape?
Simple Shapes

Math Formula!

\[ X^2 + Y^2 + Z^2 = R^2 \]
Now your computer can draw!
Library of Simple Shapes

- Sphere
- Cylinder
- Cone
- Cube
- Rectangular Prism
- Pyramid
But there’s not much one can do with simple shapes.... or is there?
Mixing and Matching

Union
Mixing and Matching

Union
Mixing and Matching

Intersection
Mixing and Matching

Intersection
Mixing and Matching

Difference
Mixing and Matching

Difference
Constructive Solid Geometry
Constructive Solid Geometry

Demo:

OpenScad
Examples
CSG Representation

• Primitive: basic shapes

• Recipe: union, intersection, diff etc ...
Three down...
One more, but this time: you tell me!
Height field/ Height Map
Height Field Representation

• Primitive: height value

• Recipe: assign a value for each point in a grid
Play at home!

Meshlab

OpenScad

They are free!
REPRESENTING 3D SHAPES (II)
-PROCEDURAL MODELING

Presented by Valentina Shin
Pull out a piece of paper.
1. Draw a circle in the middle of the paper. ($r \approx 1.5\text{in}$)
2. Draw a smaller circle \((r \approx 0.5\text{in})\) inside the previous circle on the centered on the upper half.
3. Inside the bottom half of the larger circle, little below the smaller circle draw a sideways D.
4. On the left side of the larger circle draw a large ‘L.’
5. Draw a small circle attached to the top of the ‘L.’
Do you see what you are drawing?
We can represent shapes by procedure.

Procedural Modeling
How can we *generate* a sphere?
1. Take a half moon
2. Revolve it around the center
How can we *generate* a sphere?
Change shape :: triangle
Change shape :: triangle
and many more...
Change motion:: extrude
Change motion:: extrude
Change motion:: curve
And many more...
Add parameters

 Shapes have parameters.

h = 4  
w = 2

h = 4  
w = 4

h = 5  
w = 1
Add parameters

Paths have parameters.

\[ r = 4 \]

\[ r = 2 \]
Add parameters

Generate different shapes by varying parameters

Modeling Seashells / Fowler et al., SIGGRAPH 1992
Add randomness

Add randomness to parameters or procedures to generate crowds of objects

Modeling Seashells / Fowler et al., SIGGRAPH 1992
There are *many different* procedures!

- e.g. split branch

http://matthewjamestaylor.com/blog/create-fractals-with-recursive-drawing

http://lukaszkroenke.net/projects/1.html

http://matthewjamestaylor.com/blog/create-fractals-with-recursive-drawing
There are *many different* procedures!

- e.g. rules for modifying or combining shapes
PUTTING IT ALL TOGETHER

Presented by Zoya Bylinskii
Choosing a representation

Design decisions:

• What are your **primitives**?

• What **operations** do you perform on them?

Factors to consider:

• How detailed or **accurate** is the representation?

• How much storage space is required? Is the representation **efficient**?

• What is the use case or **usability** of the representation? What should you be able to do with it?
Now let’s apply your knowledge
How to model a building?
How to model a building?

Explore some more 3D CAD models of buildings

http://www.3dcadbrowser.com/th/1/59/59264.jpg
http://www.3dcadbrowser.com/download.aspx?3dmodel=6960

https://franklyfrankie.files.wordpress.com/2011/02/building-2-model-wip.jpg
With added complexity
How to model a city?
How to model a city?

http://www.turbosquid.com/3d-models/cosmetic-set-3-3d-model/420486
http://www.turbosquid.com/3d-model/building/


http://tf3dm.com/3d-models/city

Create your own paper models of buildings

http://paperhighrise.weebly.com/
How to model a city?

Demo of filming a virtual city: https://youtu.be/2xeVFoWyGIE?t=10
How to model fabric?
How to model fabric?

Learn about how knitted clothing can be computationally simulated.

See more examples of 3D printed fabrics and clothes.

http://www.elisastrozyk.de/

http://textually.org/3DPrinting/cat_3d_printing_and_the_fashionista.html

How to model hair?
How to model hair?

http://www.sharecg.com/v/57153/related/5/3d-model/blue-hair-genesis

http://forum.stabyourself.net/viewtopic.php?t=1367&start=50

http://www.theimaginestudio.com/product/3d-polygon-hair

https://www.fxguide.com/featured/brave-new-hair/

Read more about behind the scenes of Pixar’s Brave
How to model hair?

Video demo about Merinda’s hair: https://www.youtube.com/watch?v=Cecx5HVtUDY
How to model grass?
How to model grass?

Parabola

Pixar in a box
(Khan Academy)

How to model water?
How to model water?

http://bugman123.com/FluidMotion/index.html

See some more fluid motion simulations

Behind the scenes of sea storm effects:
https://www.youtube.com/watch?v=Tmm4BQX8TCQ
Putting it all together

Use your new knowledge to look at the world
Putting it all together

Seeing behind the special effects:

https://www.youtube.com/watch?v=MnQLjZSX7xM
Application of 3D Modeling
Films, games, simulations


https://ev111426.wordpress.com/2014/09/26/5/

A nice review of the 3D Production Pipeline!
Reconstructions

Learn more about forensic face reconstruction


http://schools-wikipedia.org/wp/n/Neanderthal.htm
Product design

screen shots from mental ray render

screen shots from 3ds max shader

Game Art: Game Car Model
Details: Uses texture size of 512 x 512 pixels
My task involved creating the modeling and texturing the given model.

Student Name: Aviram das
Contact: info@alga.in
Date: Aug 2010

http://sibuchandradas.deviantart.com/art/Game-Car-Model-212091849
Urban Planning

Learn more about how 3D city planning software works! (and how it's like Minecraft)

Robotics

https://kaylah3dmodelling.wordpress.com/2015/03/04/rigging/
3D printing

http://deezmaker.com/bukobot/
Learn more!

- Khan Academy’s “Pixar in a box”: https://www.khanacademy.org/partner-content/pixar
- Behind special effects: https://www.youtube.com/channel/UCjnYk44Aj9E634TPucpIXnQ
- The 3D production pipeline: https://ev111426.wordpress.com/2014/09/26/5/
- Geometrical shapes visualized: http://virtualmathmuseum.org/

And the other links sprinkled throughout the slides!