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. <u>There are rules to keep in mind!</u>

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.

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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. <u>There are 2 rules to keep in mind!</u>

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 partner's instructions to draw a picture. <u>There are 2 rules to keep in mind!</u>

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.


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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. <u>There are 2 rules to keep in mind!</u>

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. <u>There are 2 rules to keep in mind!</u>

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.

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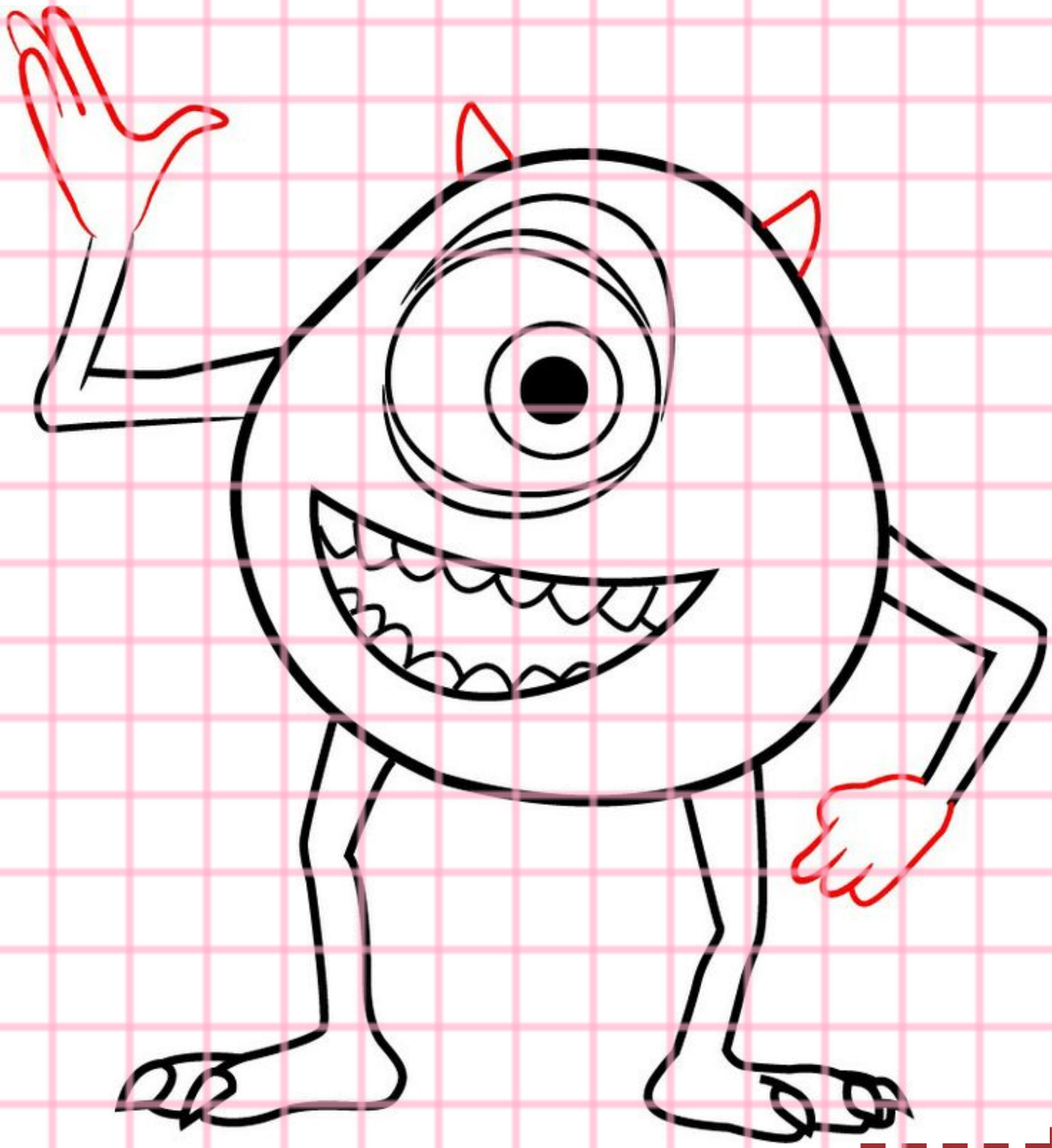

CSAIL

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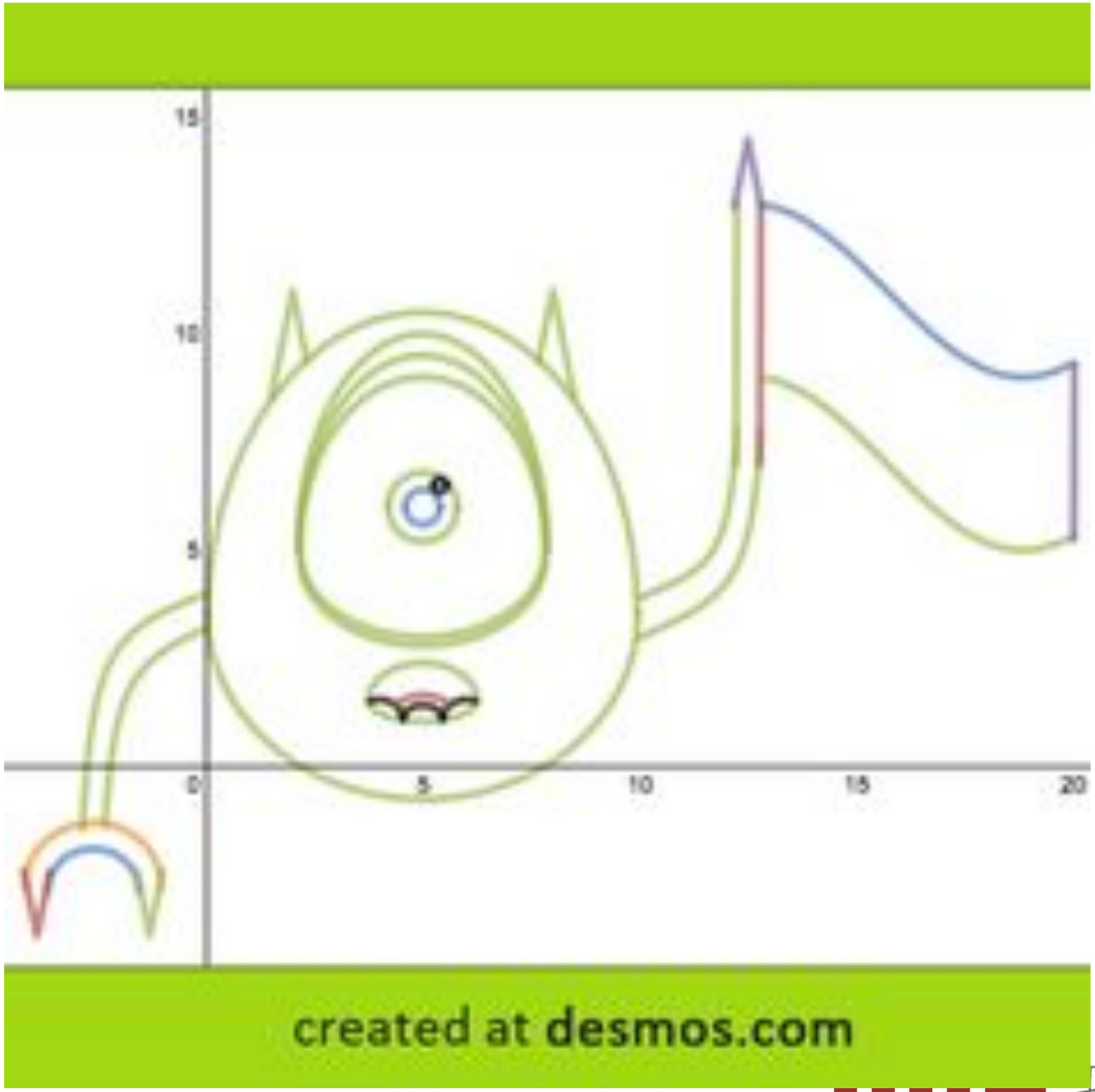
After the activity…

- 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?

[MIKE] SEO YE

CSAIL

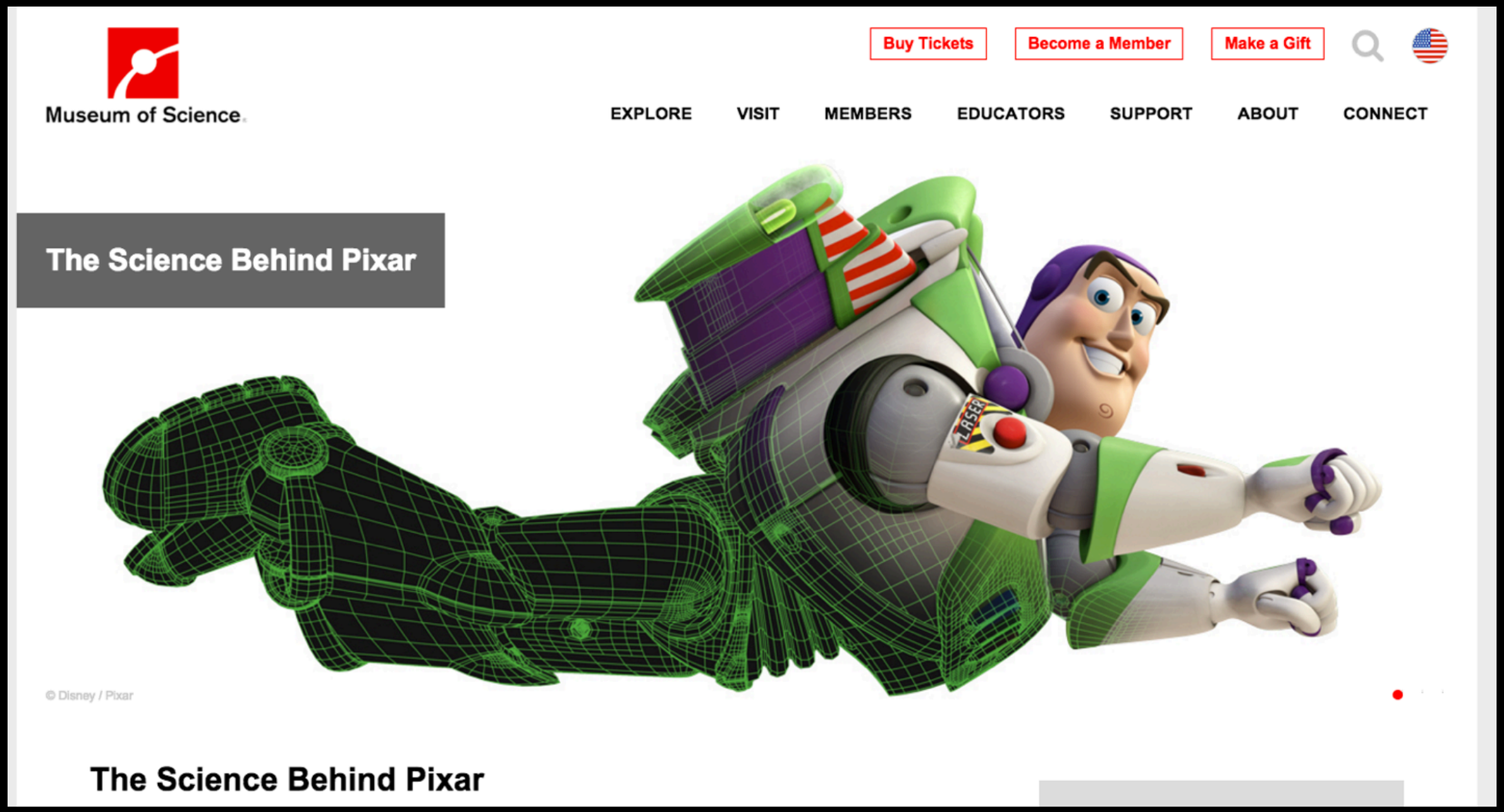


CSAIL

Presented by Zoya Bylinskii

INTRODUCTION

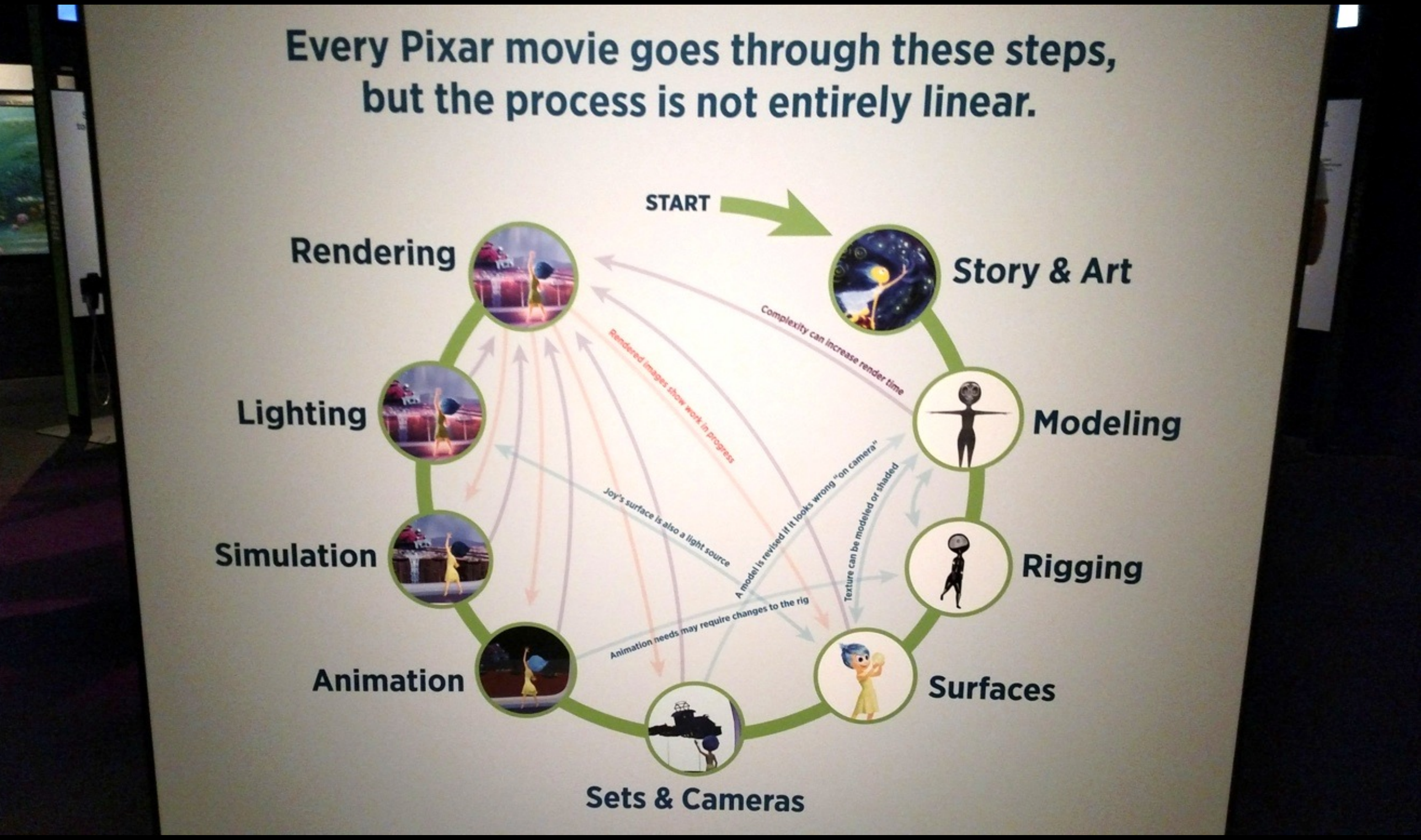
who's been to MOS recently?



Learn more about the exhibit

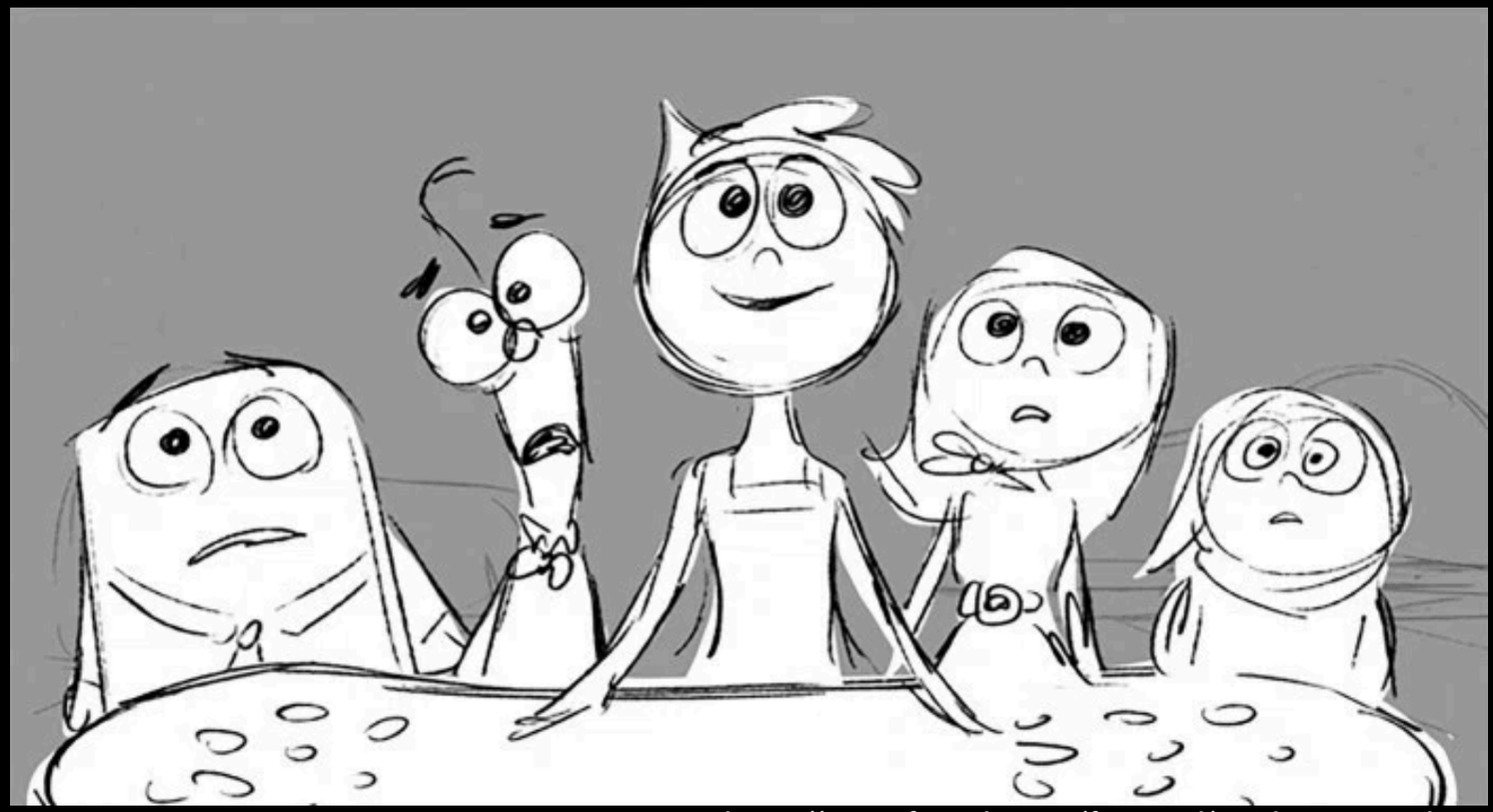
http://www.mos.org/exhibits/the-science-behind-pixar

Watch this intro: https://youtu.be/3Iu1Z0h1i1Y?t=47



on exhibit at the Boston Museum of Science

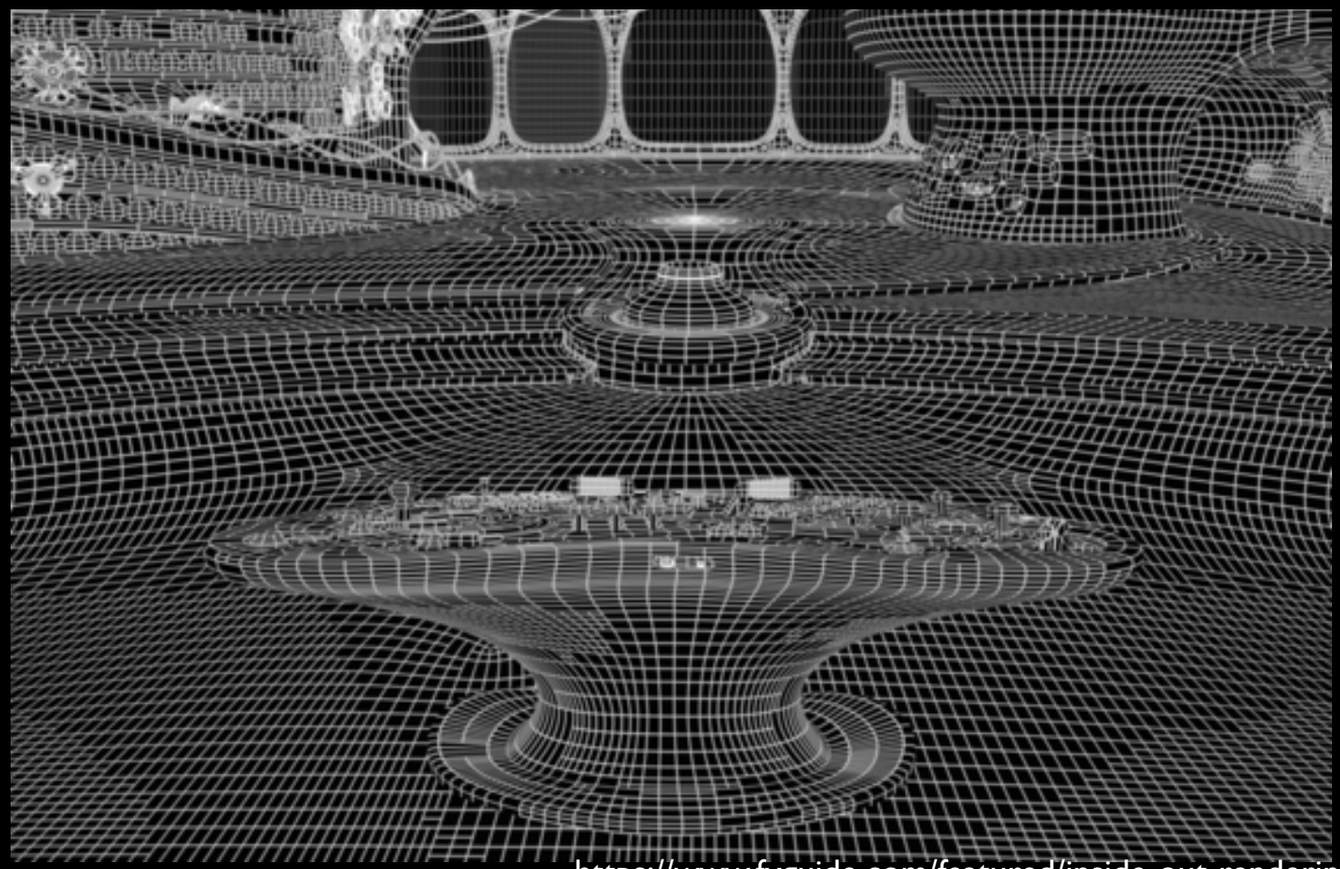
SKETCHING



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

http://www.treddi.com/app/en/articoli/pagina/924-the-making-of-the-dark-knight

MODELING



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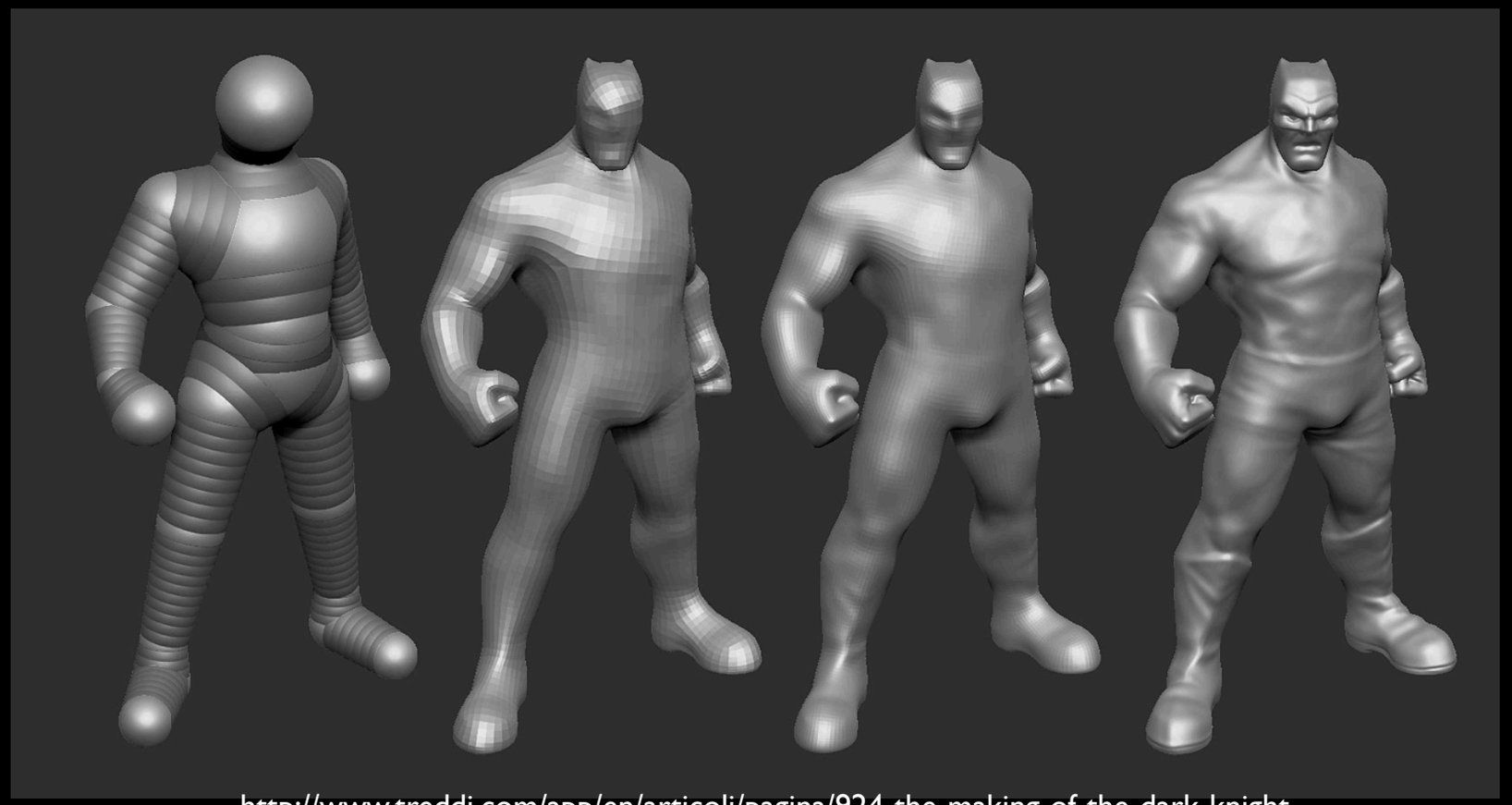

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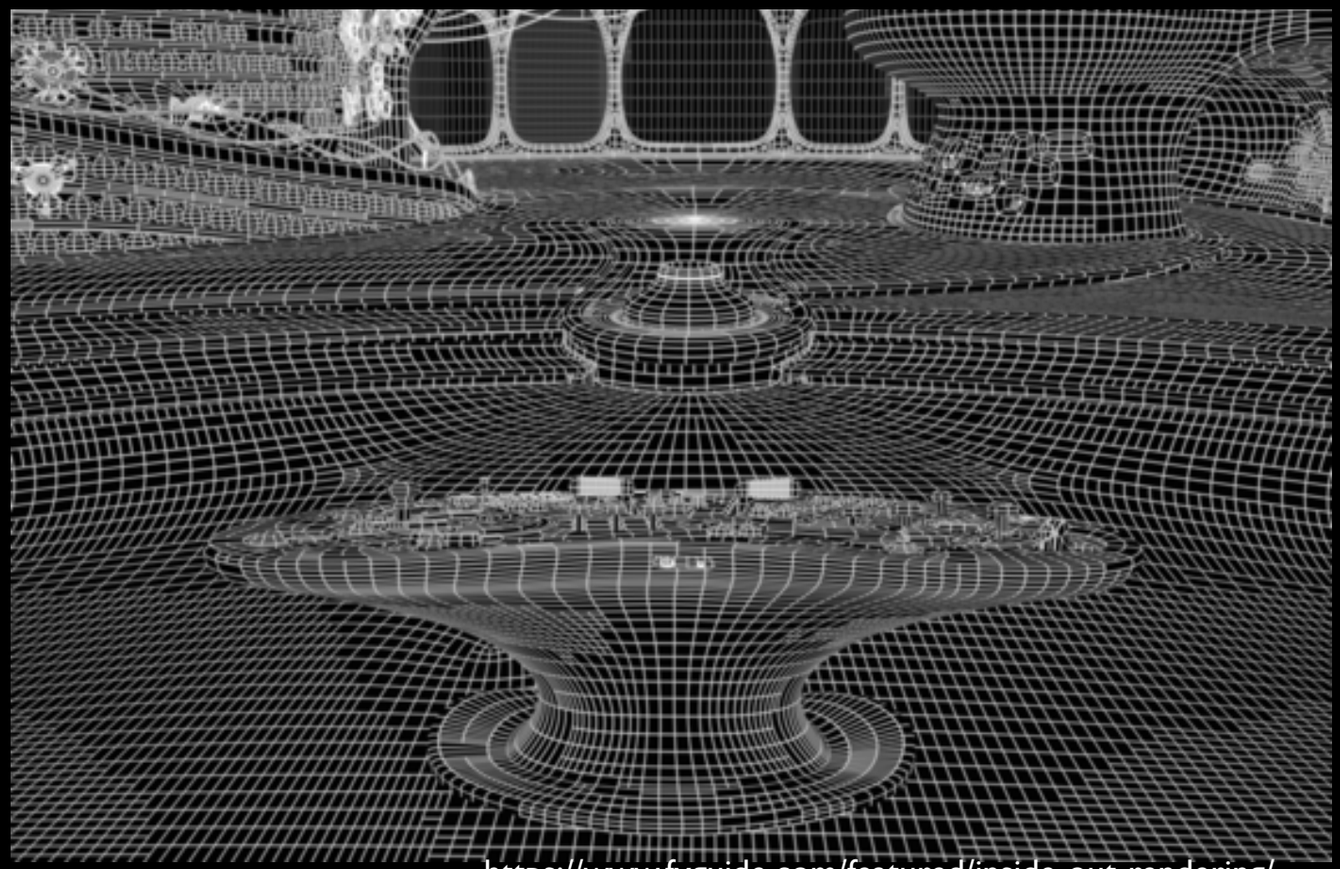
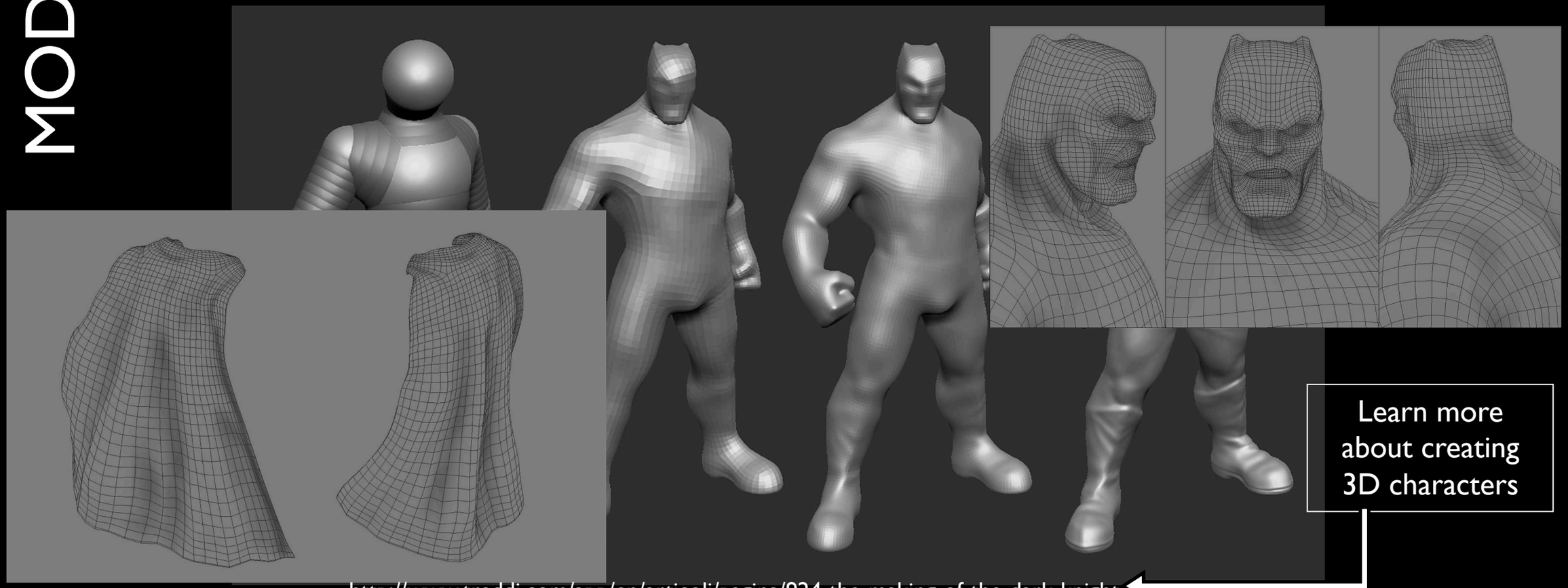
MODELING



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

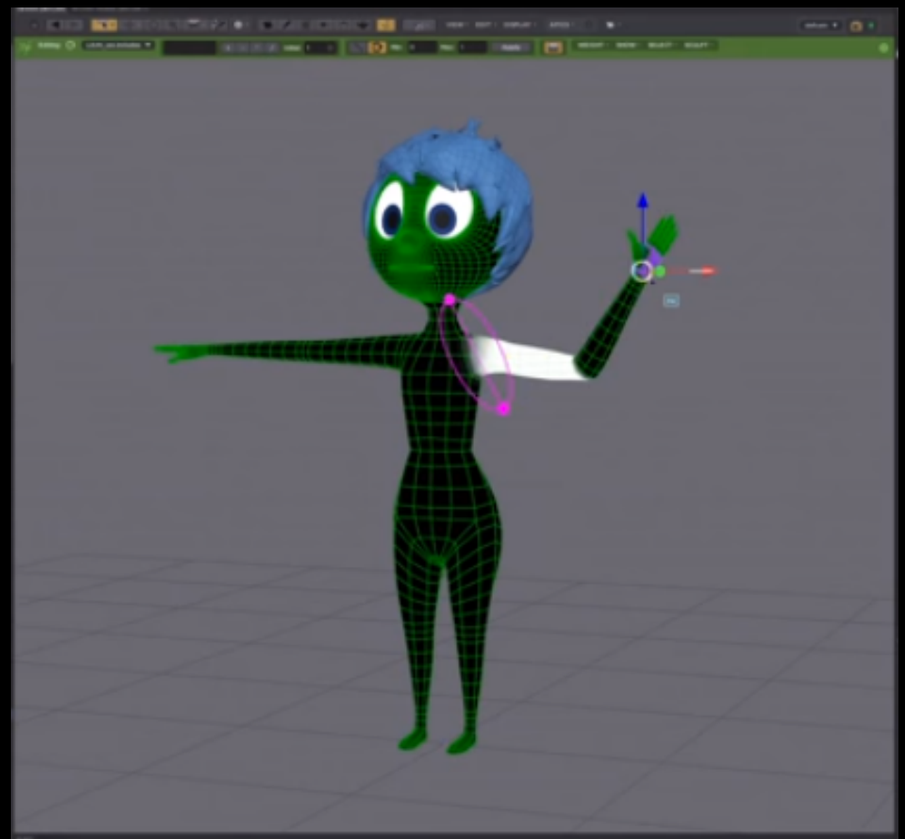
Learn more about behind the scenes of inside-out



http://www.treddi.com/app/en/articoli/pagina/924-the-making-of-the-dark-knight

Learn more about creating 3D characters

RIGGING



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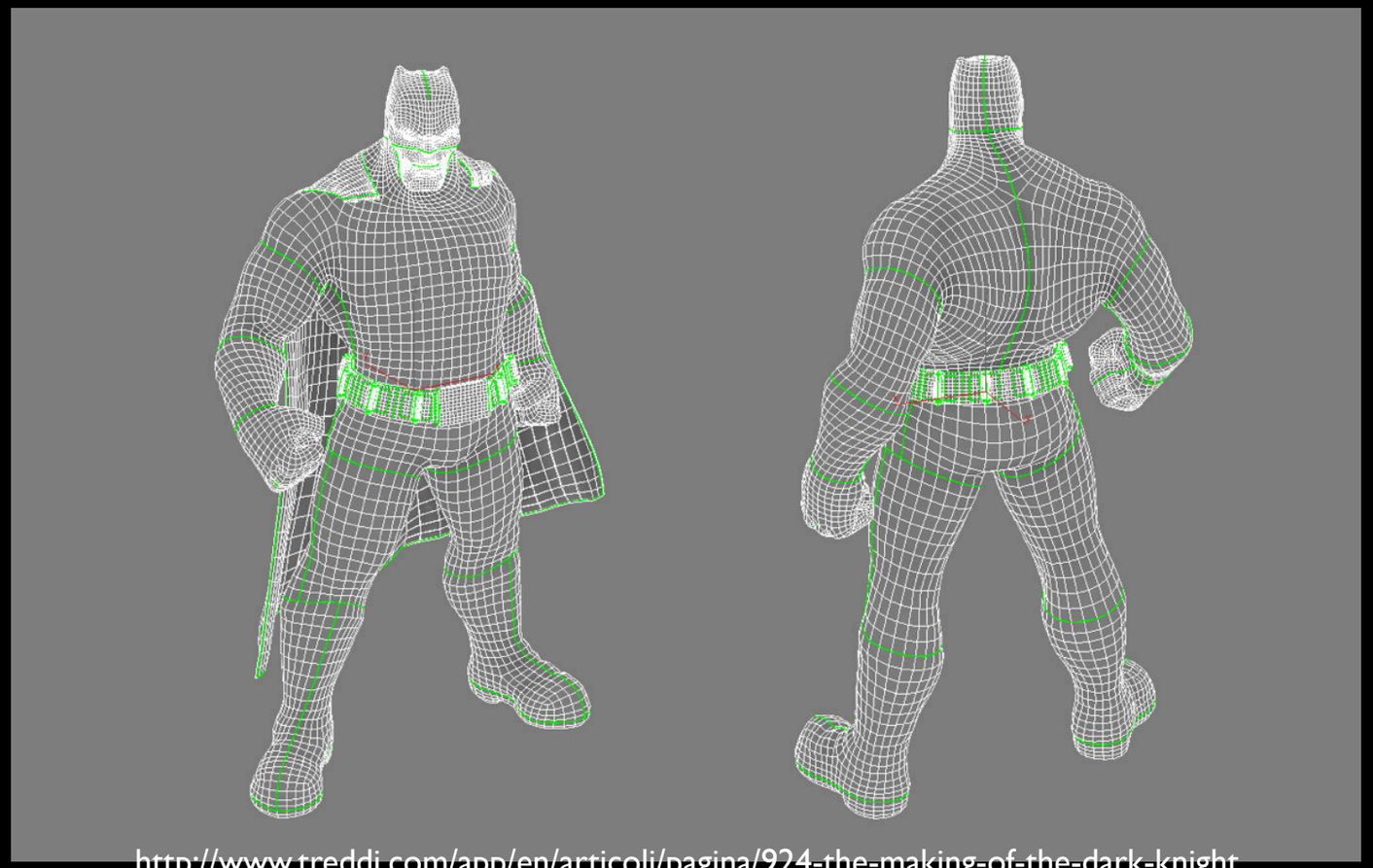

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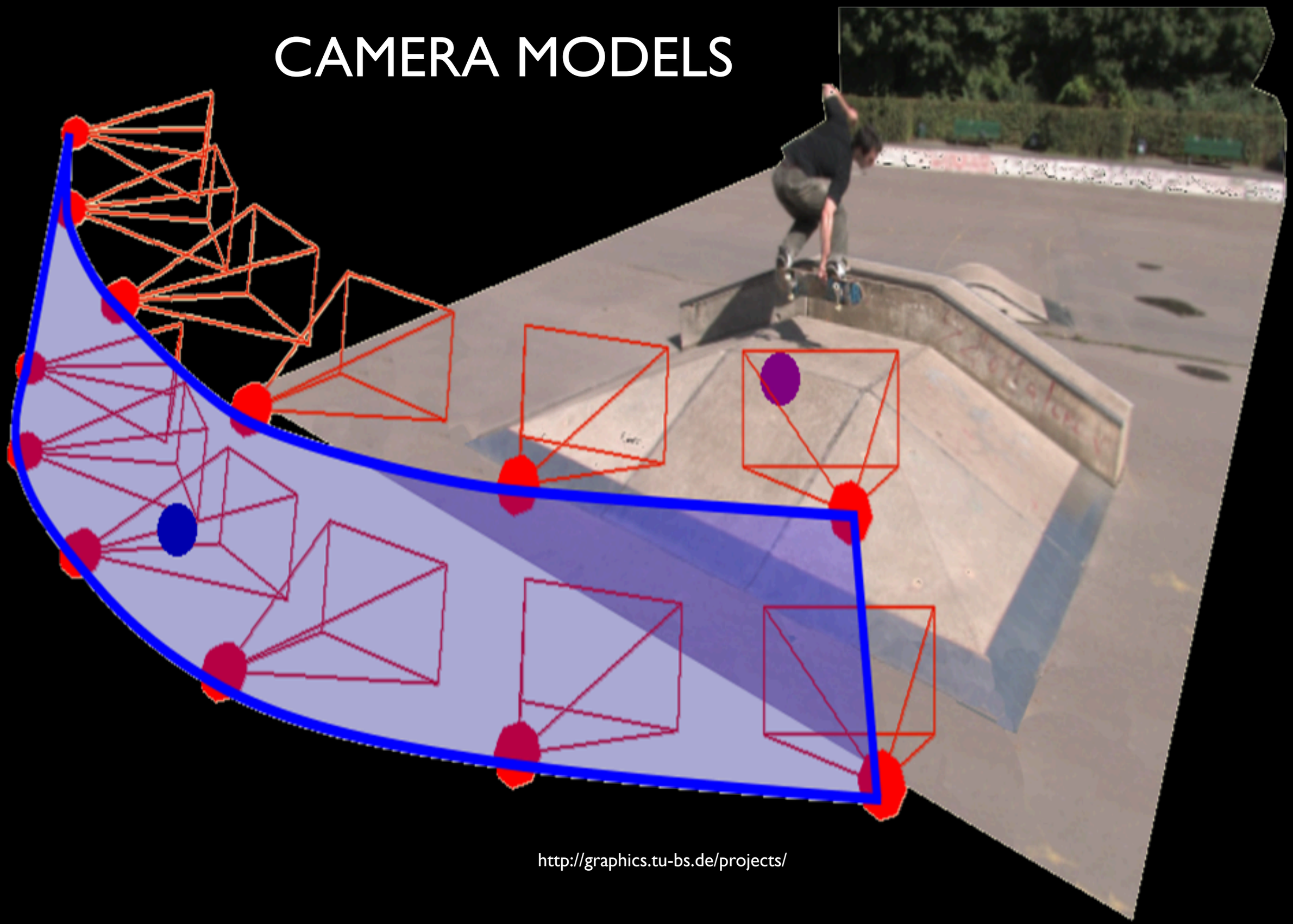
CAMERA MODELS

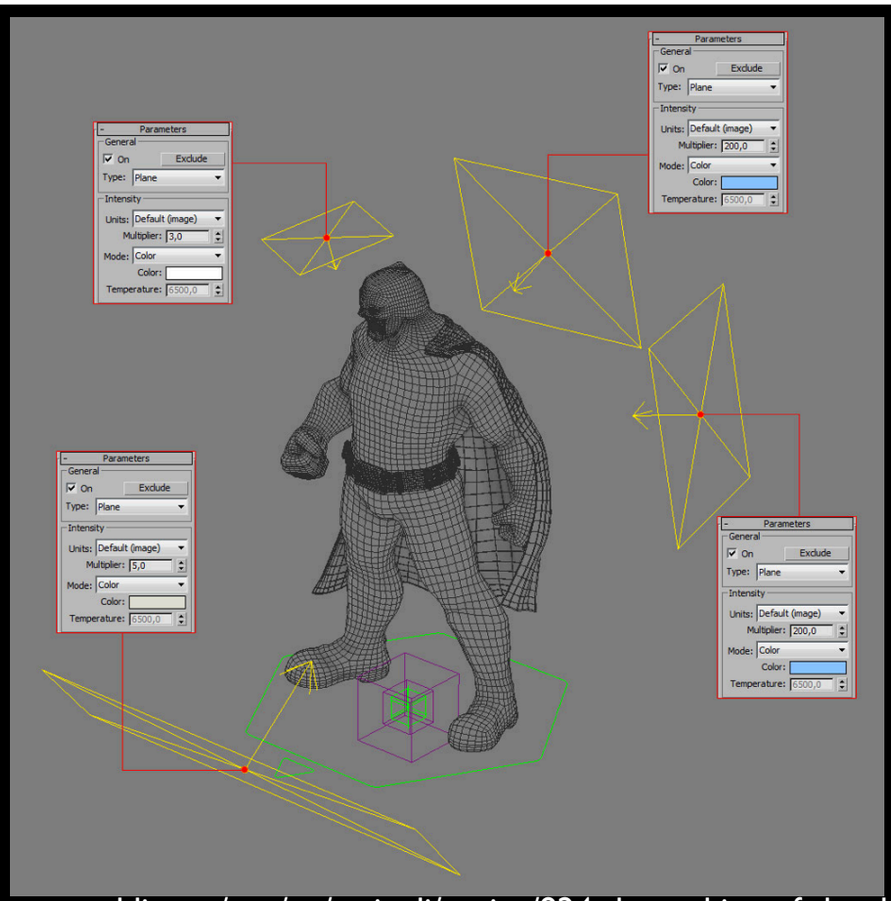


http://graphics.tu-bs.de/projects/

MODELS

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

CAMERA



http://www.treddi.com/app/en/articoli/pagina/924-the-making-of-the-dark-knight

LIGHTING & RENDERING

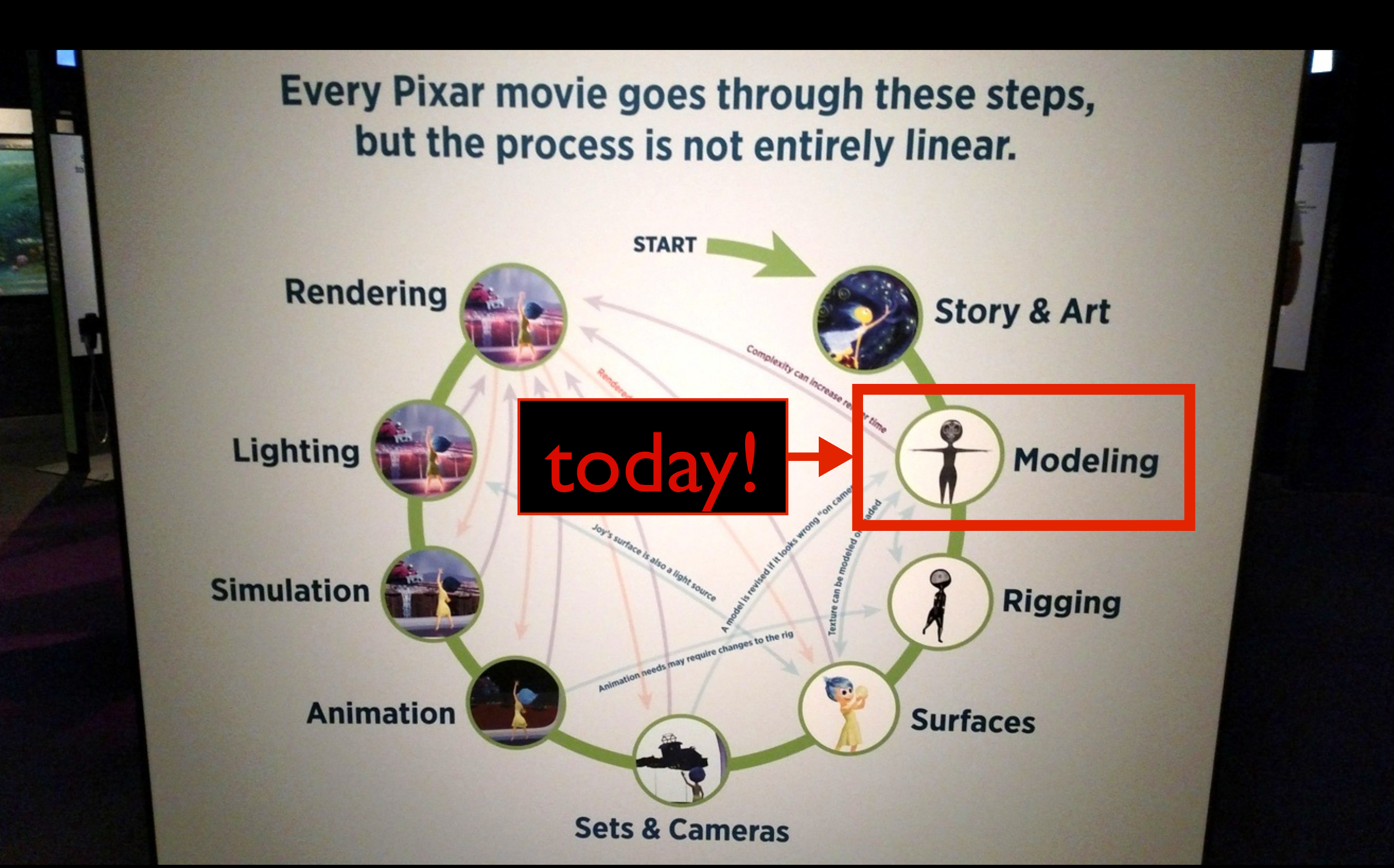
http://www.businessinsider.my/inside-out-review-2015-5/#dSgQ1fYR4uJX0ZmJ.97

http://www.treddi.com/app/en/articoli/pagina/924-the-making-of-the-dark-knight

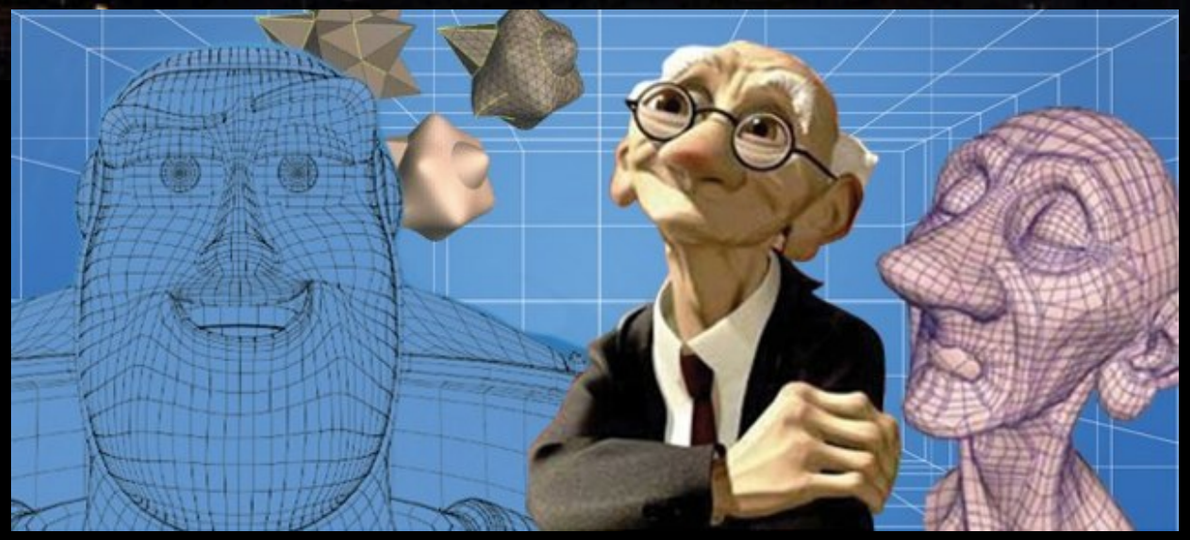
PRODUCT

FINISHED

http://www.treddi.com/app/en/articoli/pagina/924-the-making-of-the-dark-knight



on exhibit at the Boston Museum of Science



http://www.scientificcomputing.com/news/2015/07/building-computational-thinkers-exhibit-offers-unique-look-science-behind-pixar
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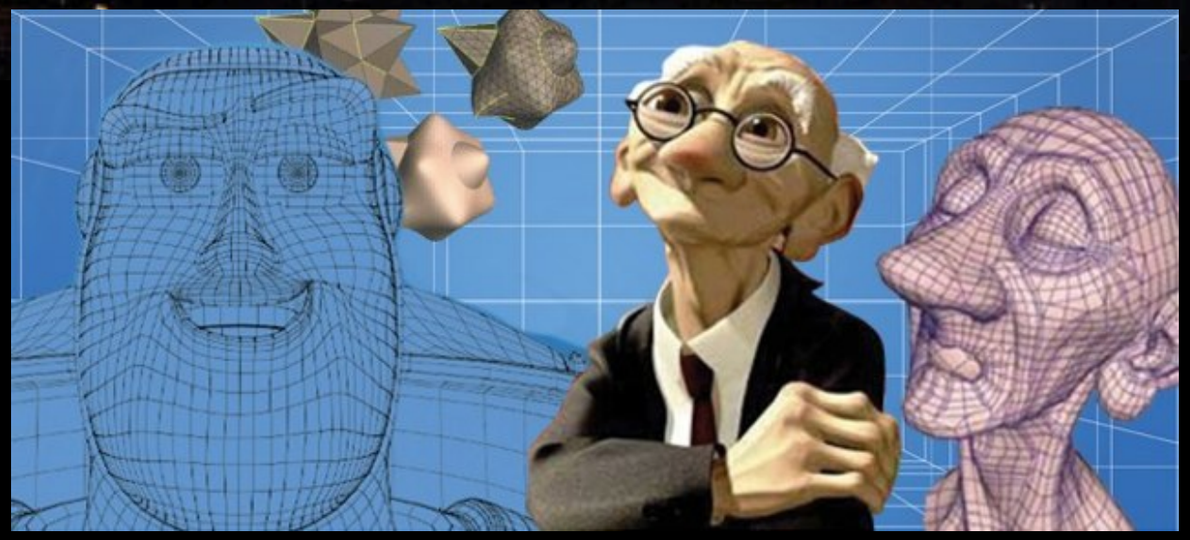
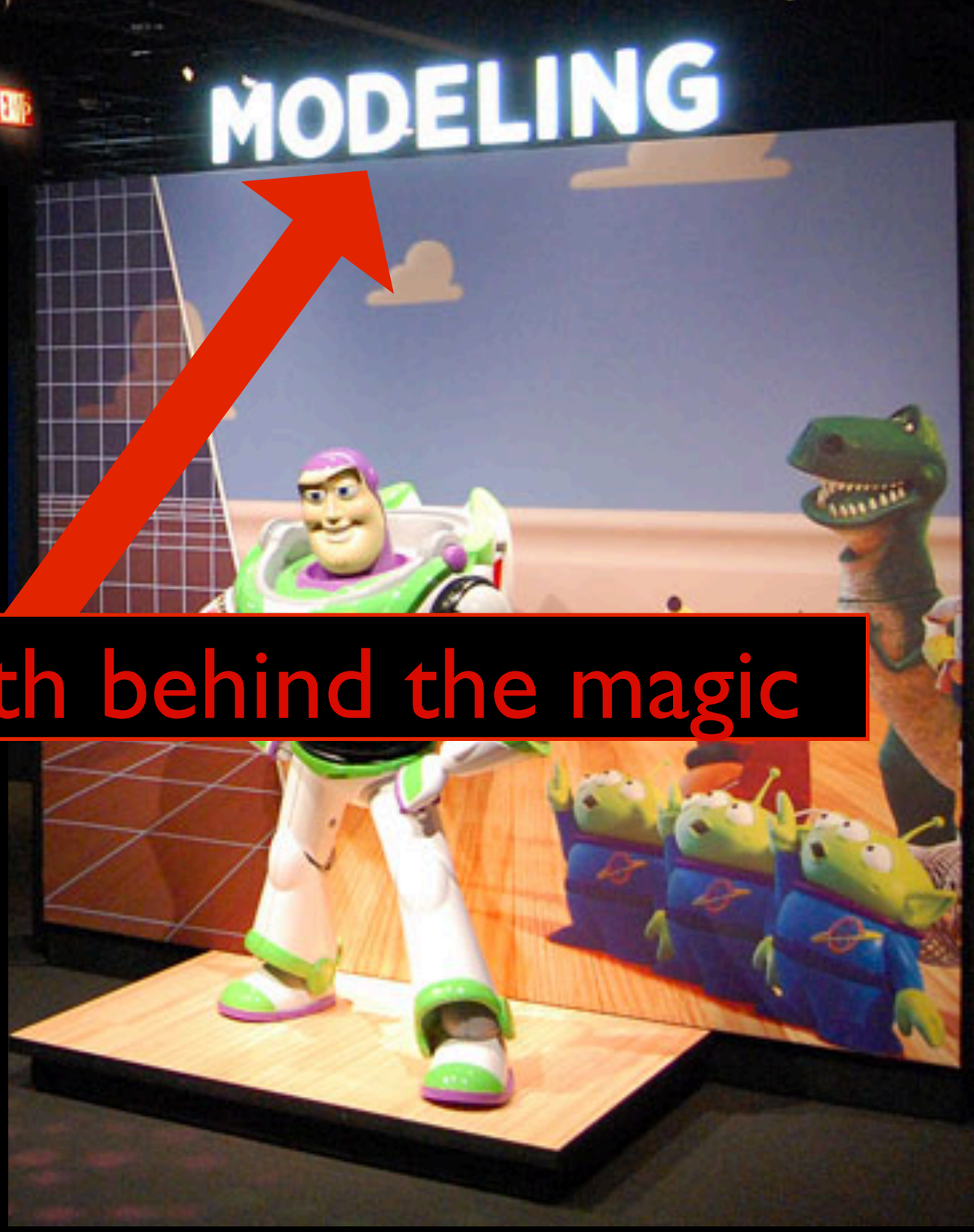




The math behind the magic

http://www.scientificcomputing.com/news/2015/07/building-computational-thinkers-exhibit-offers-unique-look-science-behind-pixar

http://f55d79cad48039c4fa06-0020fa3f48c62e813577a1c89a12b3b4.r24.cf1.rackcdn.com/COmmentary_Math-in-pixar.jpg

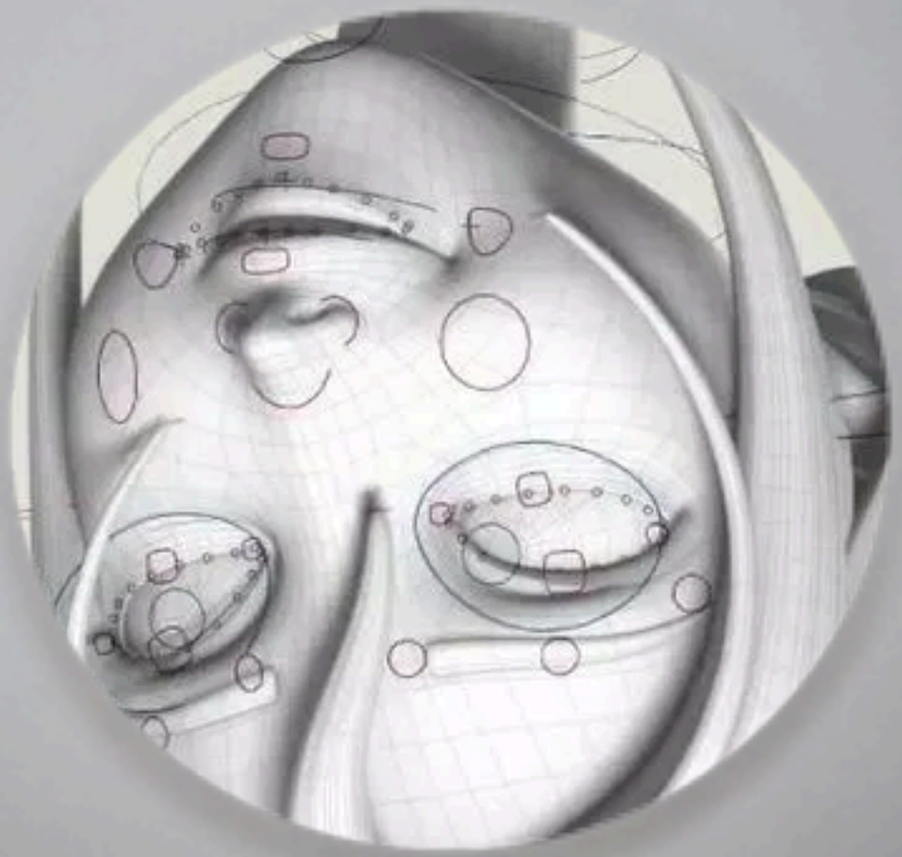
A new way
to look
at the world

https://www.pinterest.com/jessicamegan8/minions/


984673
Explore some 3D models of Pixar cars
http://www.gandoza.com/disney-pixar-cars-2-characters-3d-models.html

See more examples of rigging faces for emotion simulation


ANIMSCH



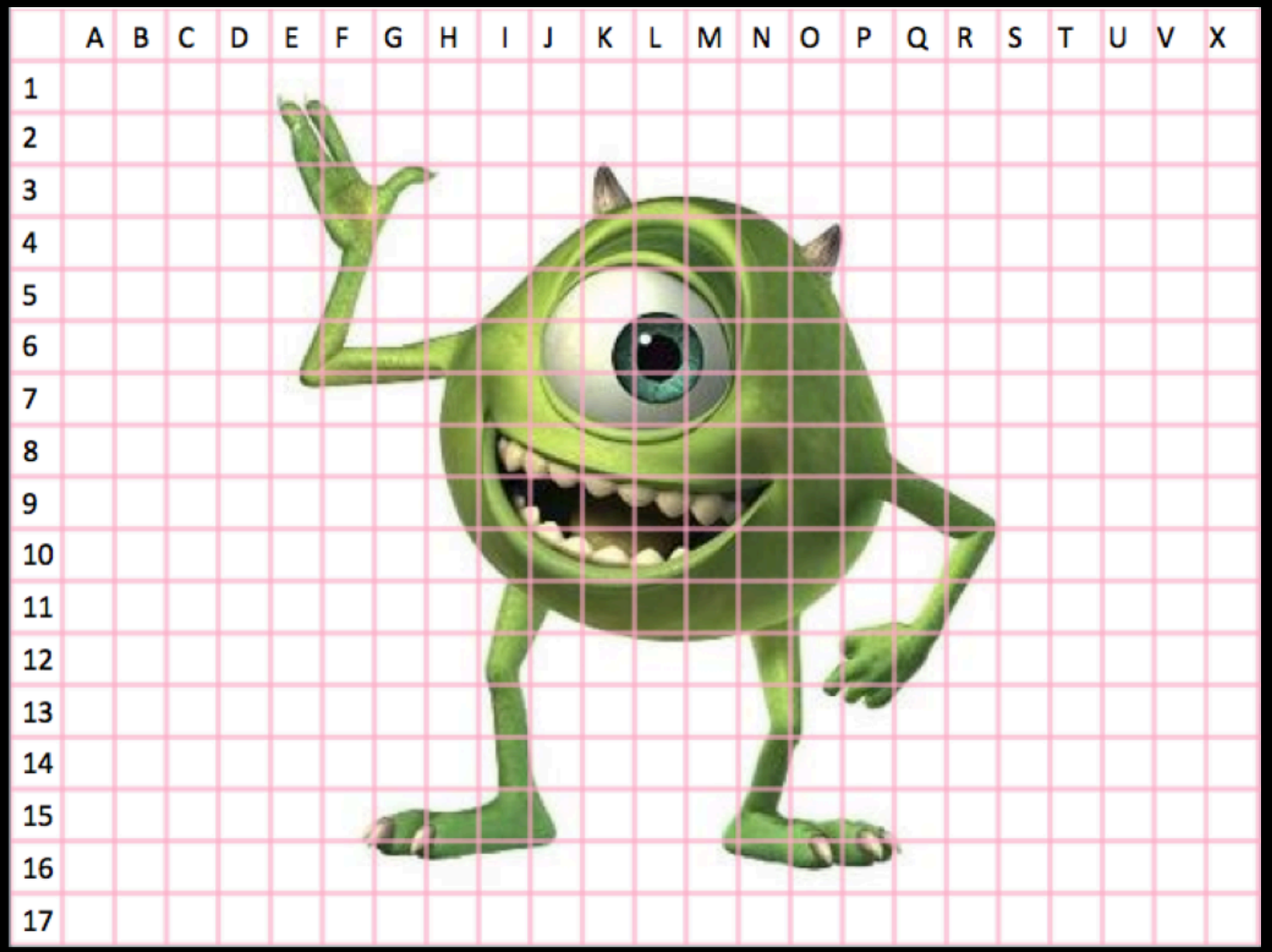
See more examples of rigging faces for emotion simulation

http://www.zbrushcentral.com/showthread.php?72270-Mei-HMC-15-expressions

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**?

Presented by Adriana Schulz

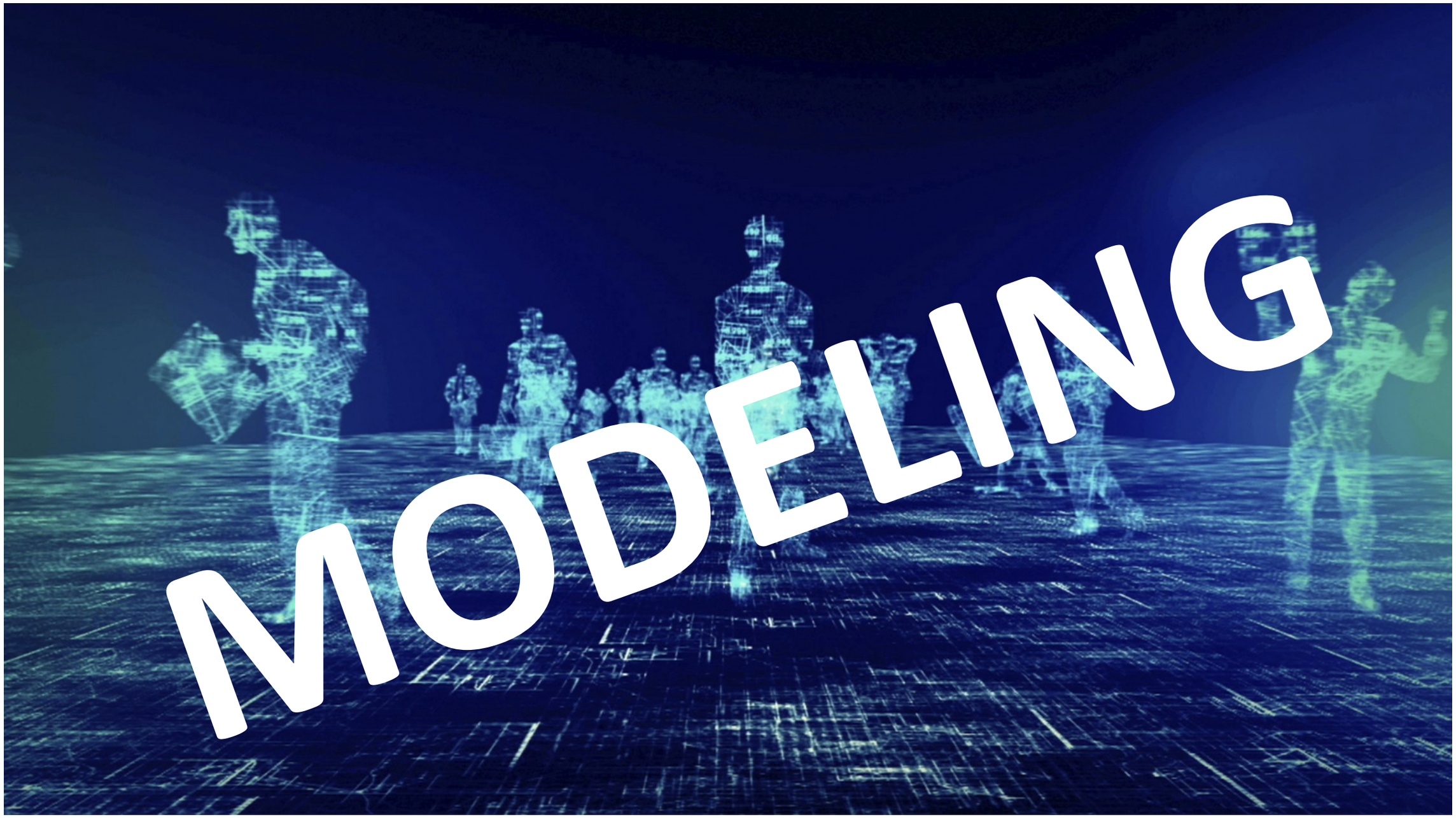
REPRESENTING 3D SHAPES (I)

-VOXELS, TRIANGLE MESH, CSG, HEIGHT FIELD

Representing 3D Shapes

Virtual World

Virtual World



Modeling is DESCRIBING the shape of objects to the computer

Modeling is DESCRIBING the shape of objects to the computer

REPRESENTATION

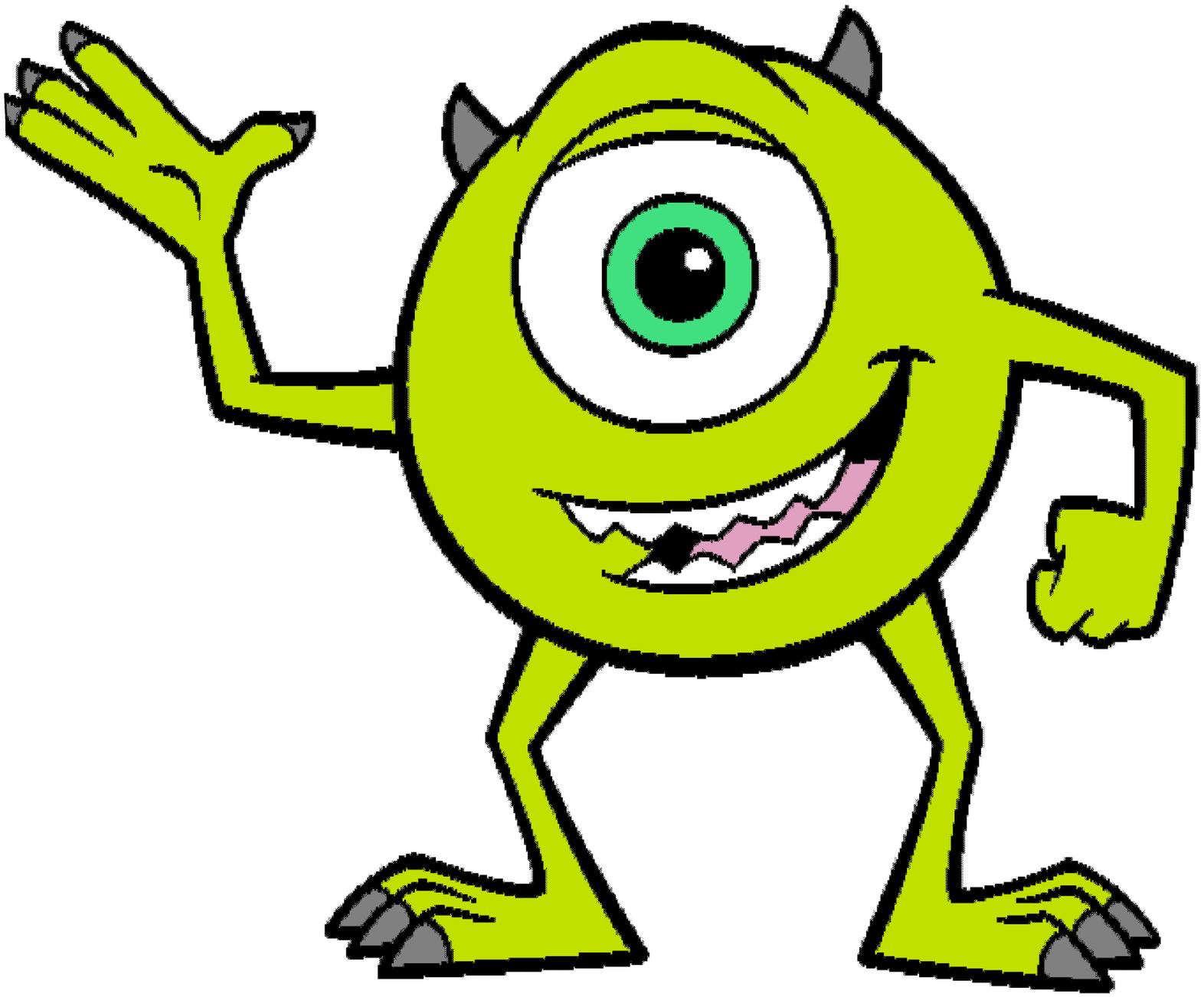
3D Model

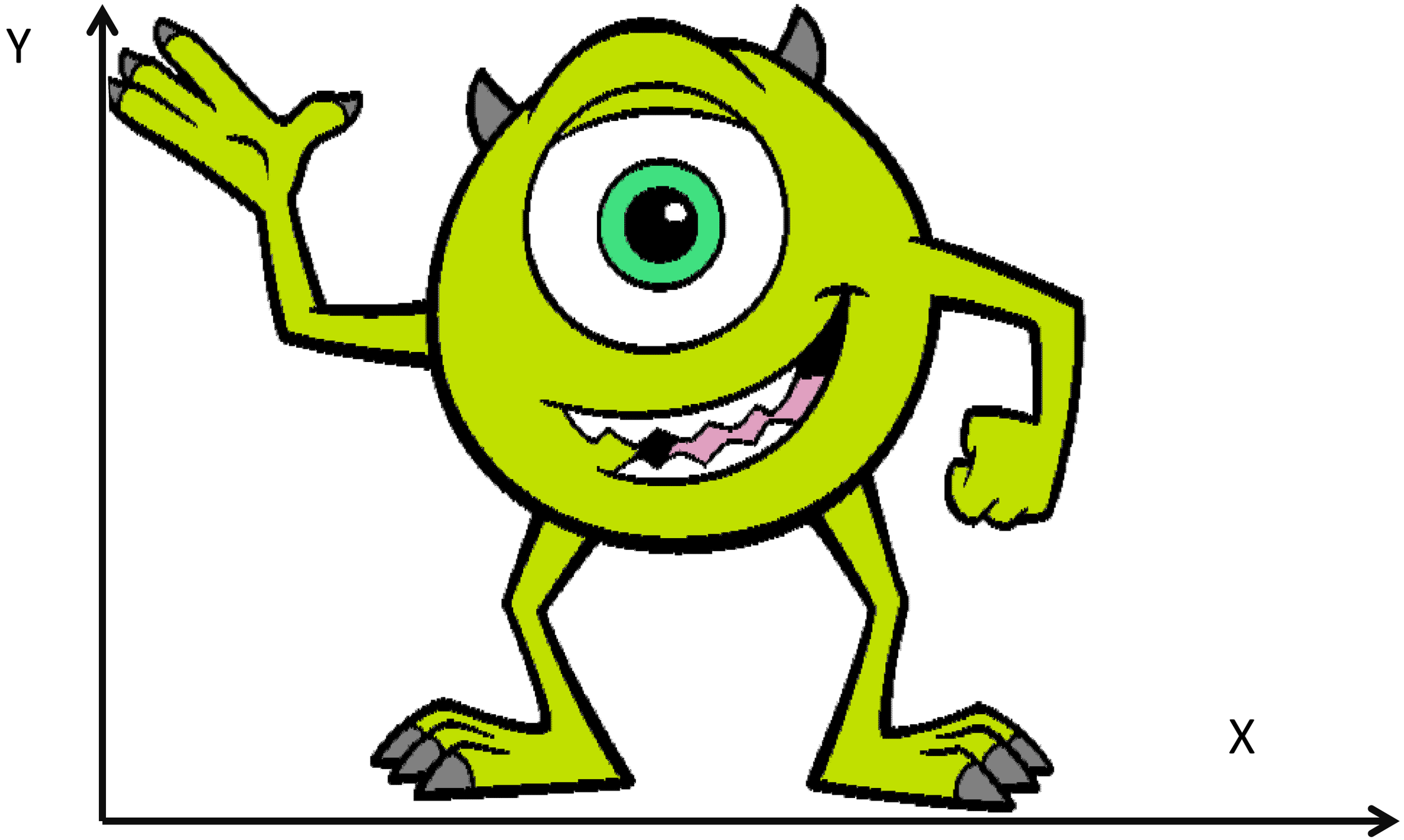
3D Shape

3D Geometry

Representation

Many ways to do this!

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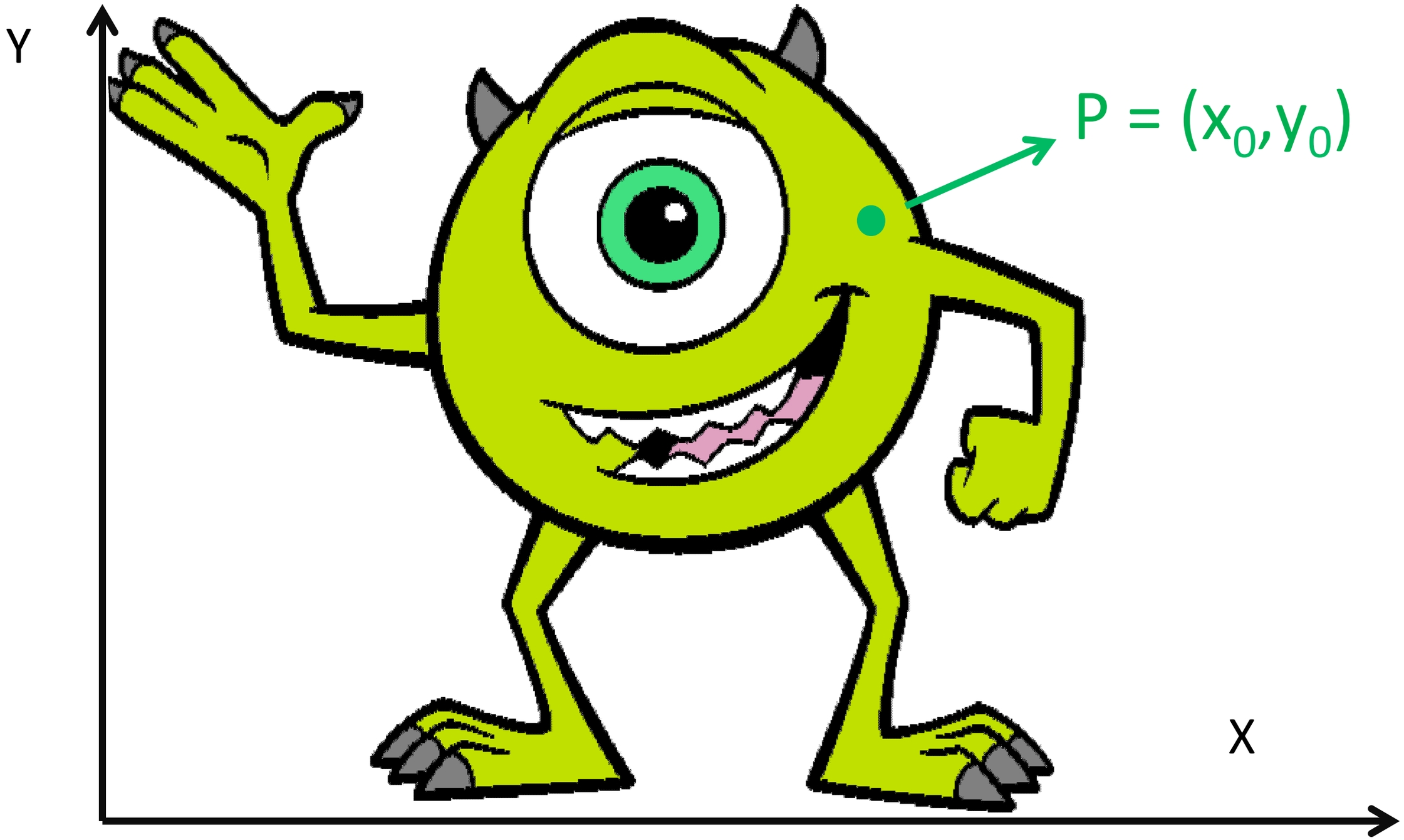
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P = (x0,y0)
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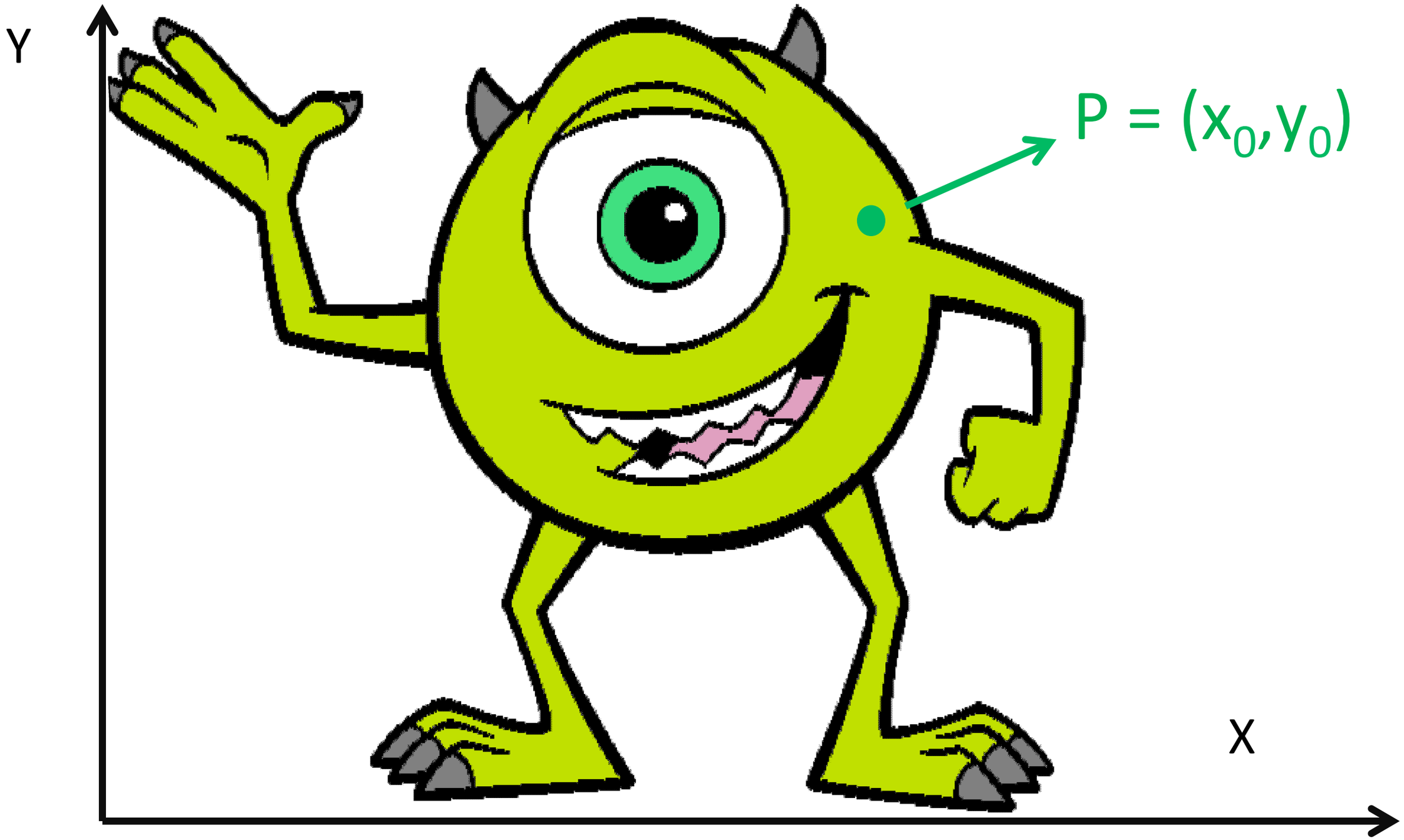
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P = (x0,y0)
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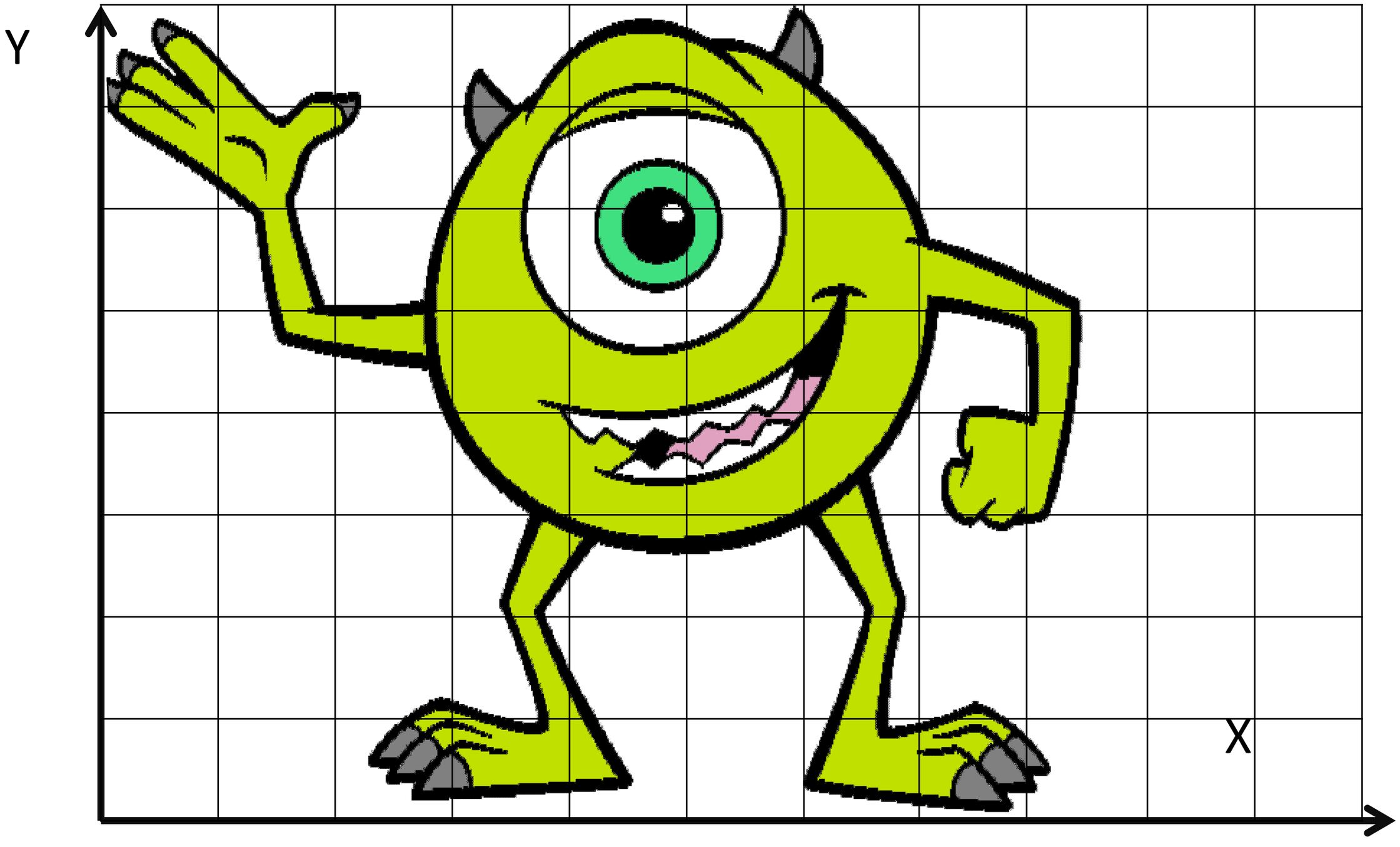
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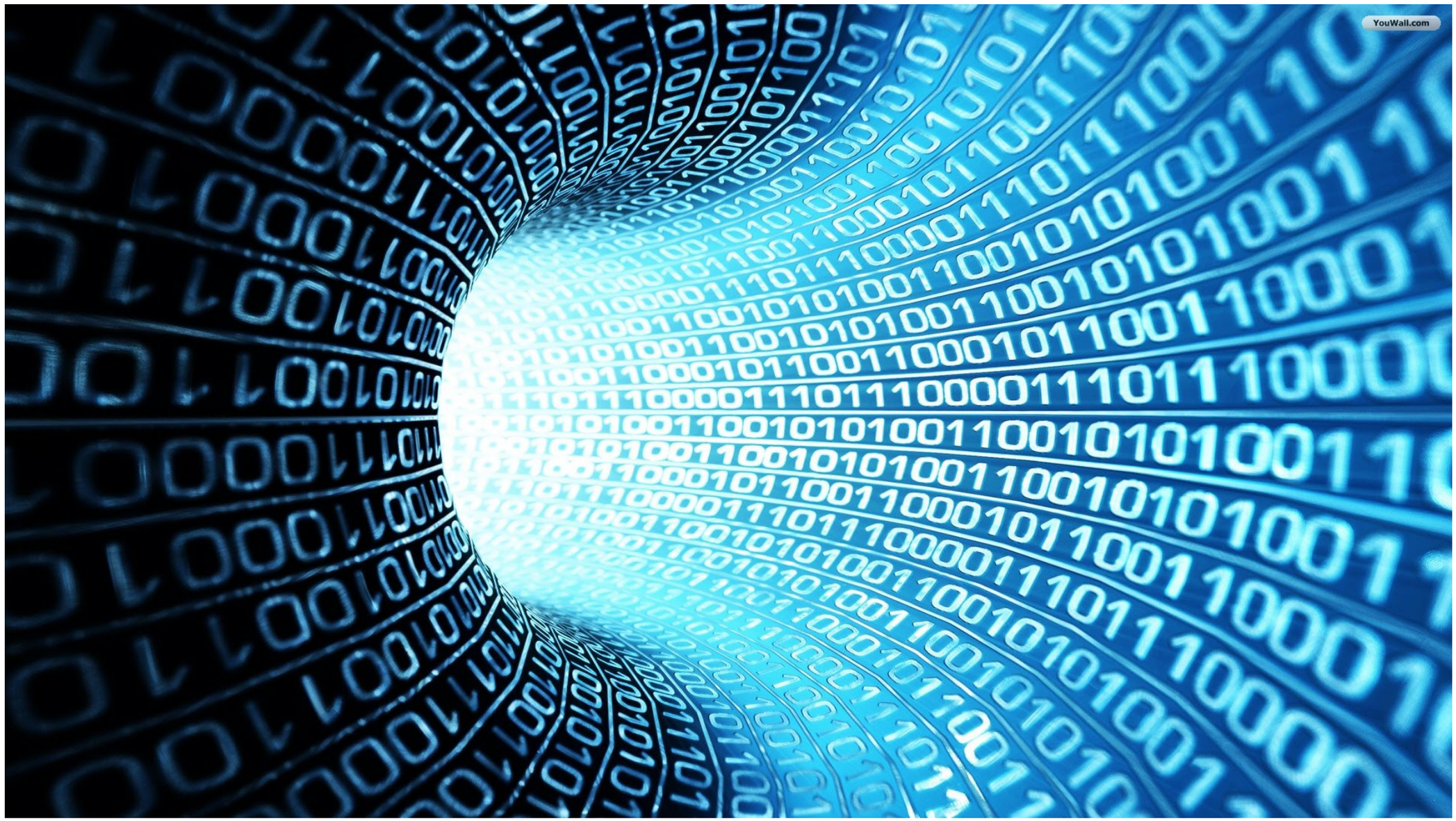
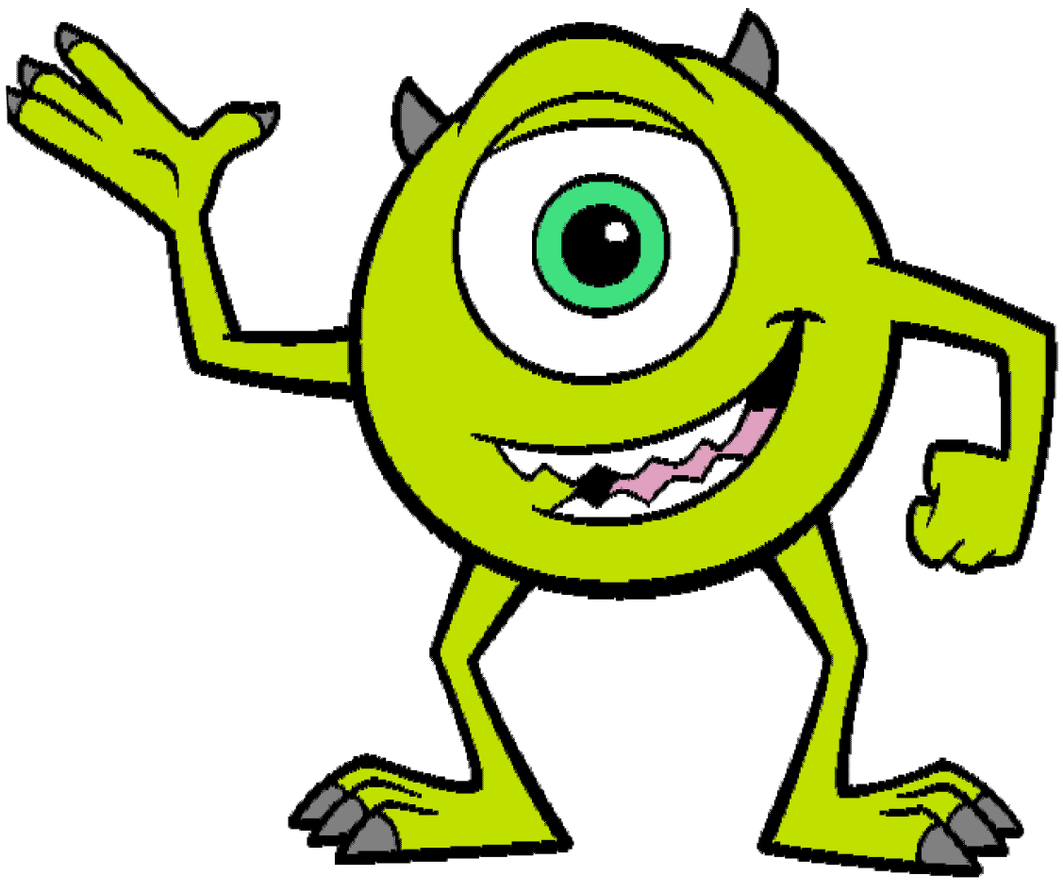
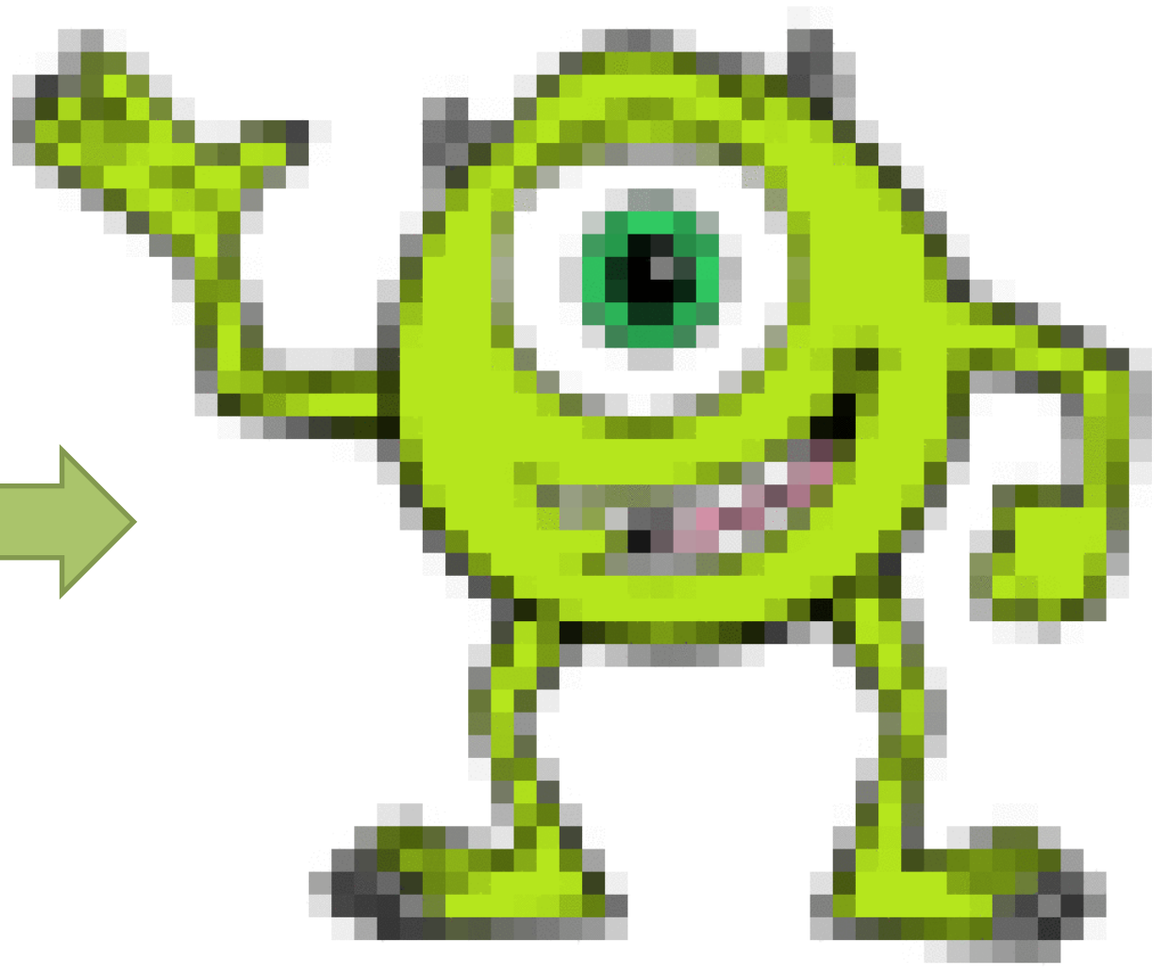
Discretization



Digital Pictures

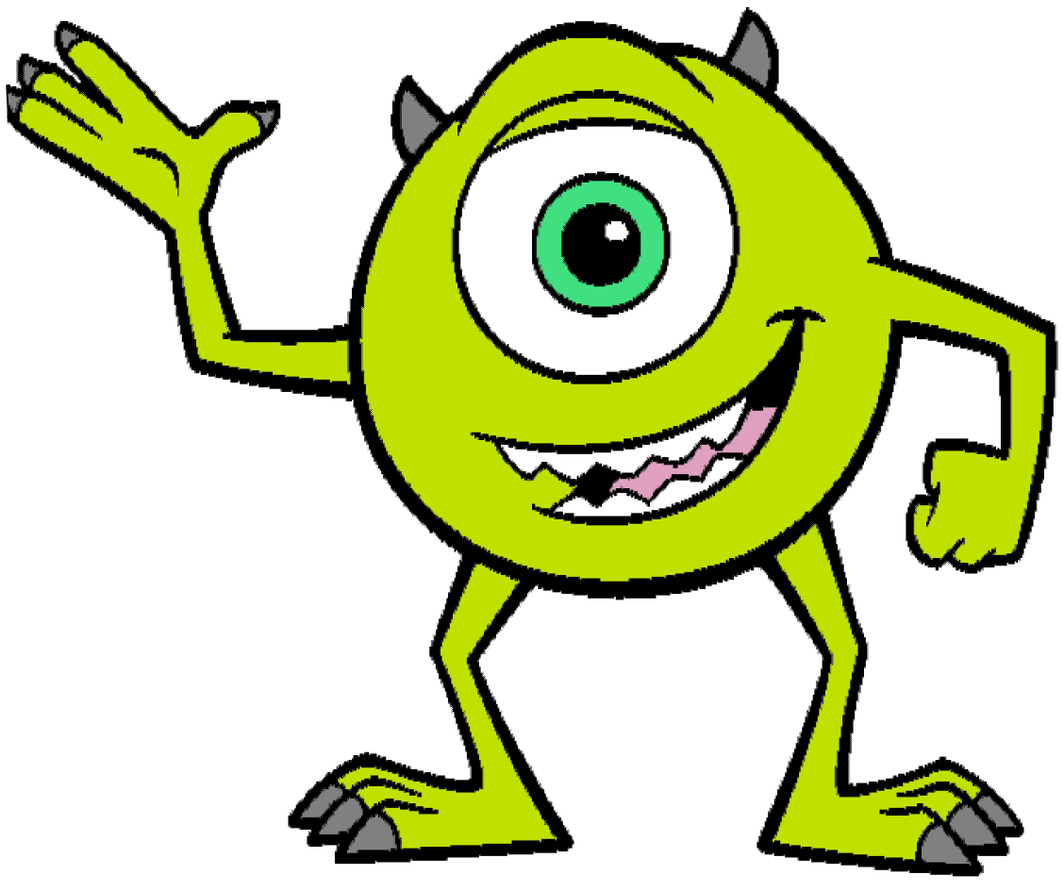


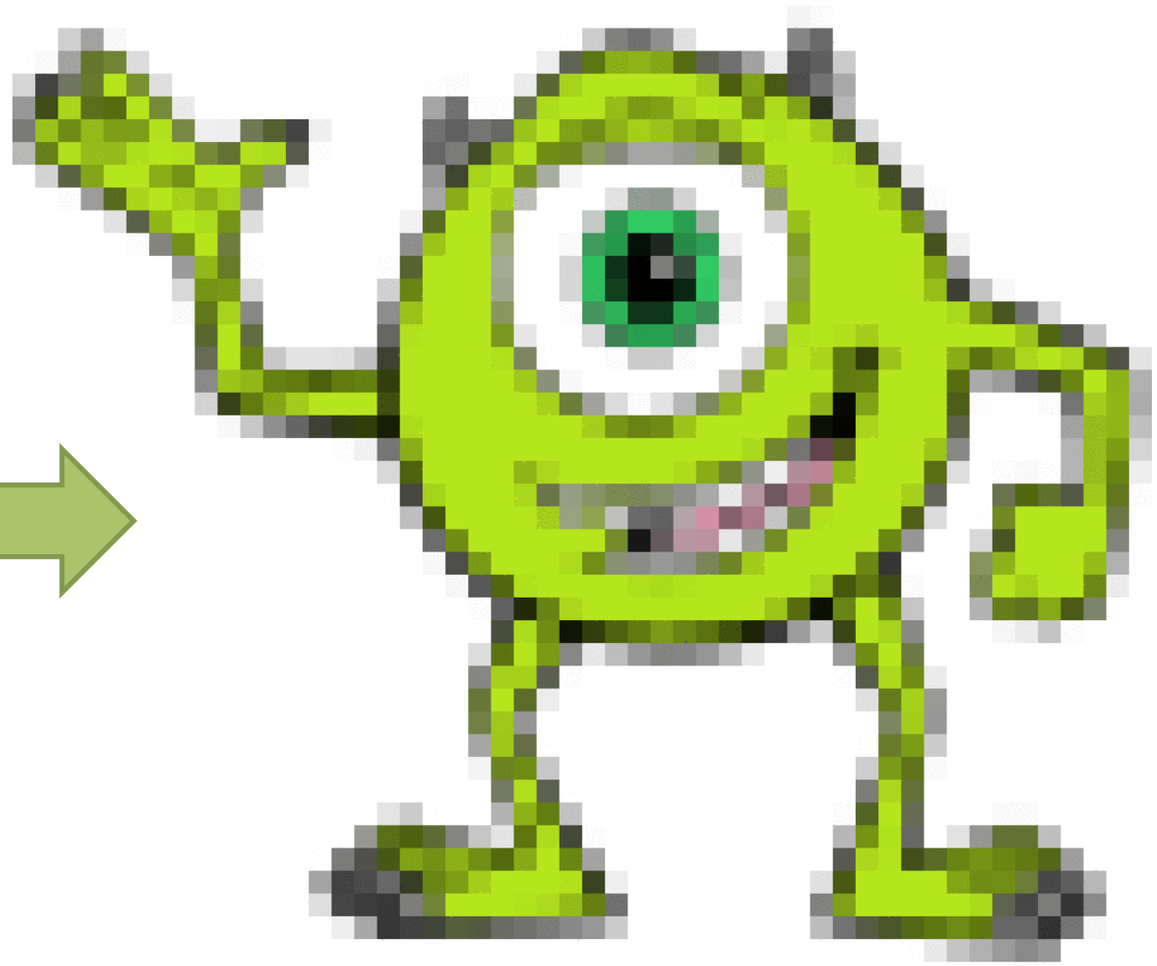


Picture

Color for every element

Digital Pictures

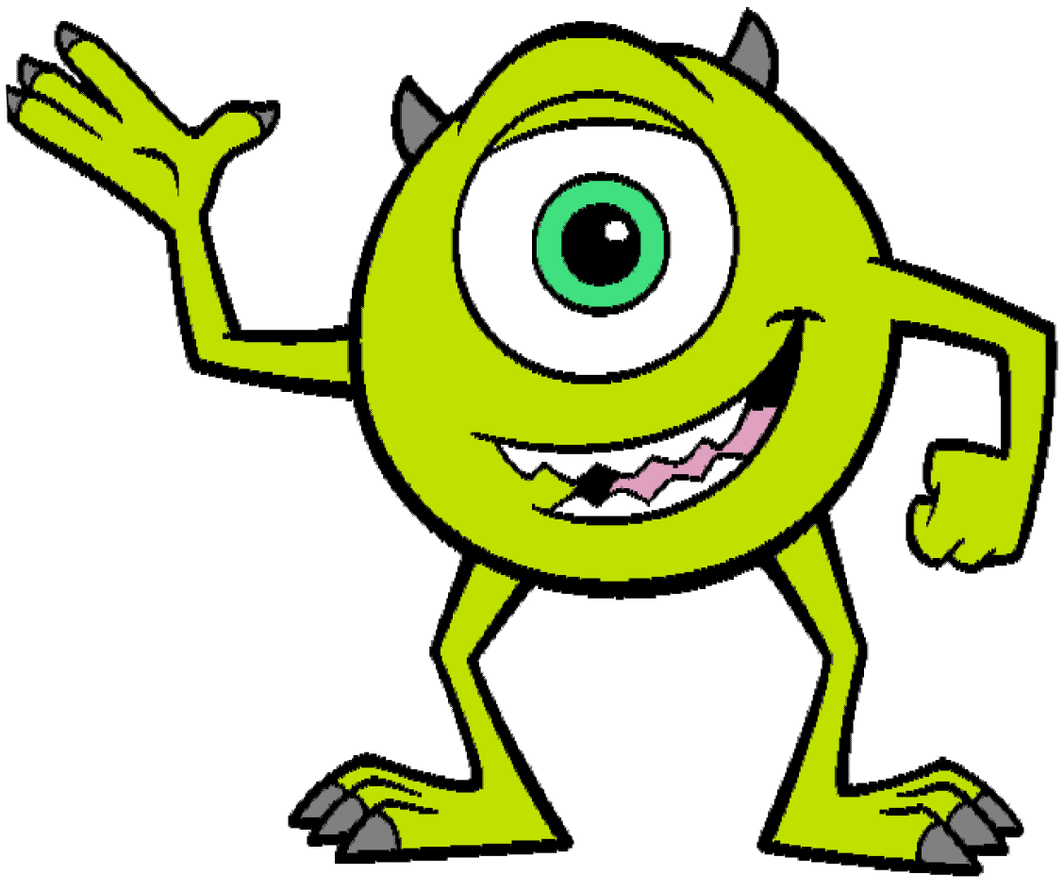




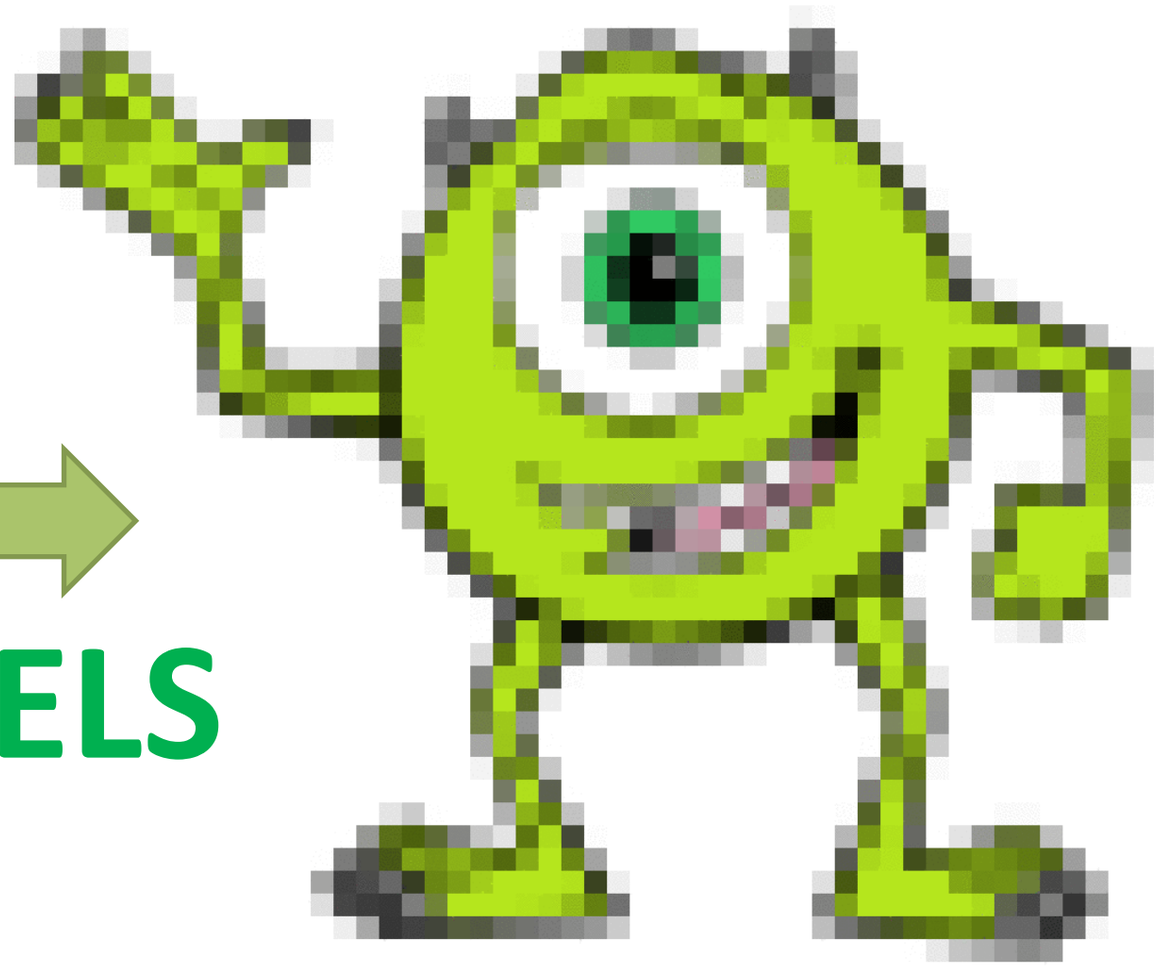
Picture

Color for every element

Digital Pictures



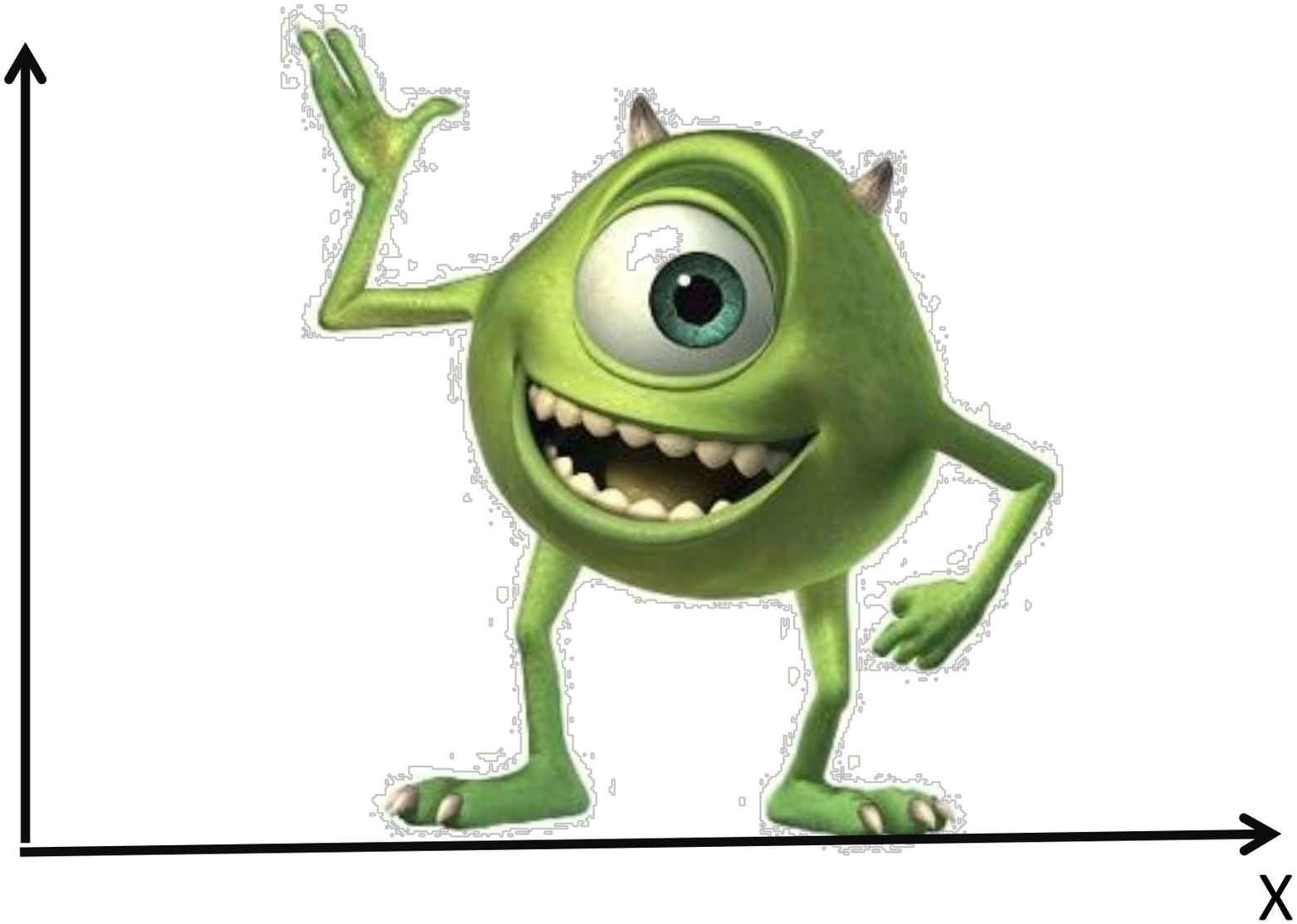
PIXELS



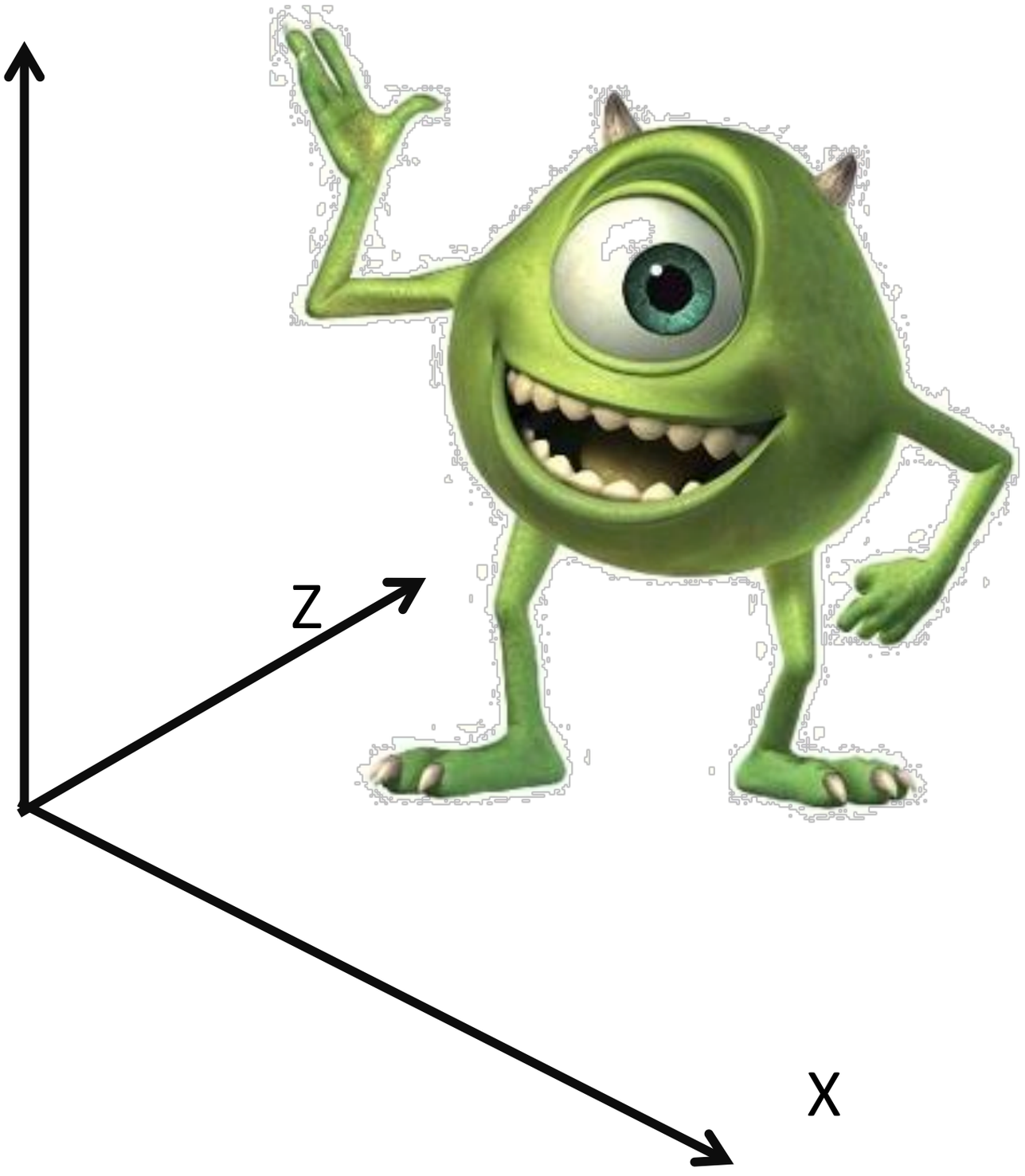
Picture

Color for every element

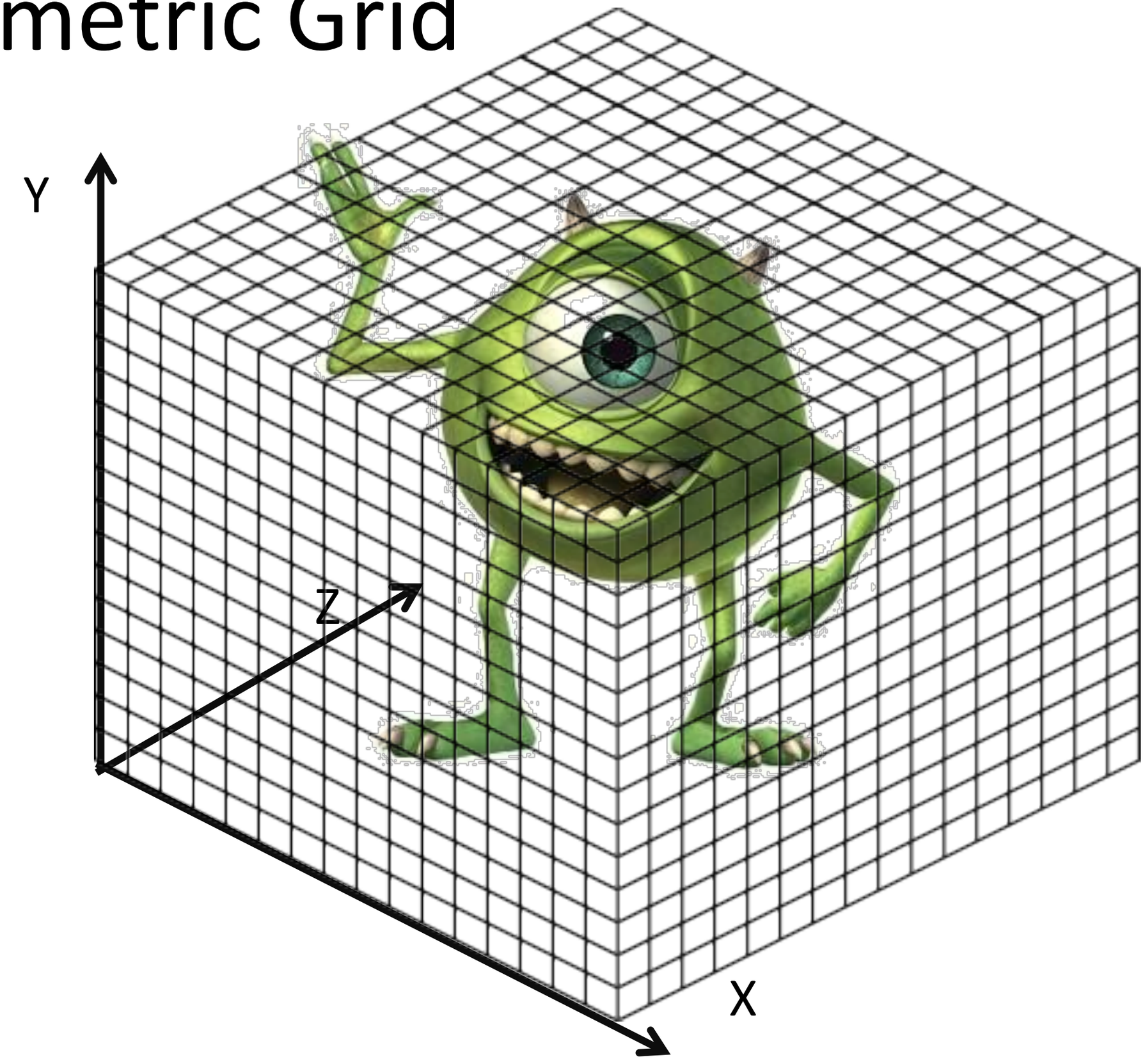
What about 3D?



What about 3D?

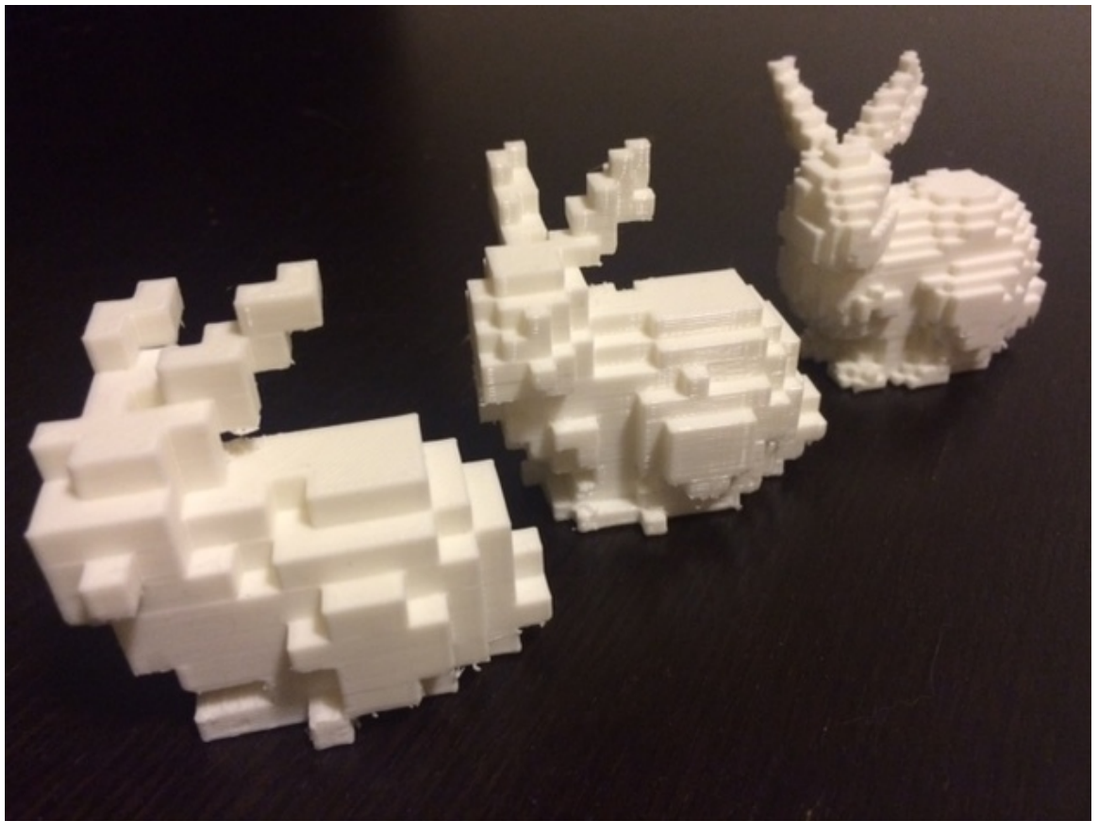


Volumetric Grid



3D Geometry

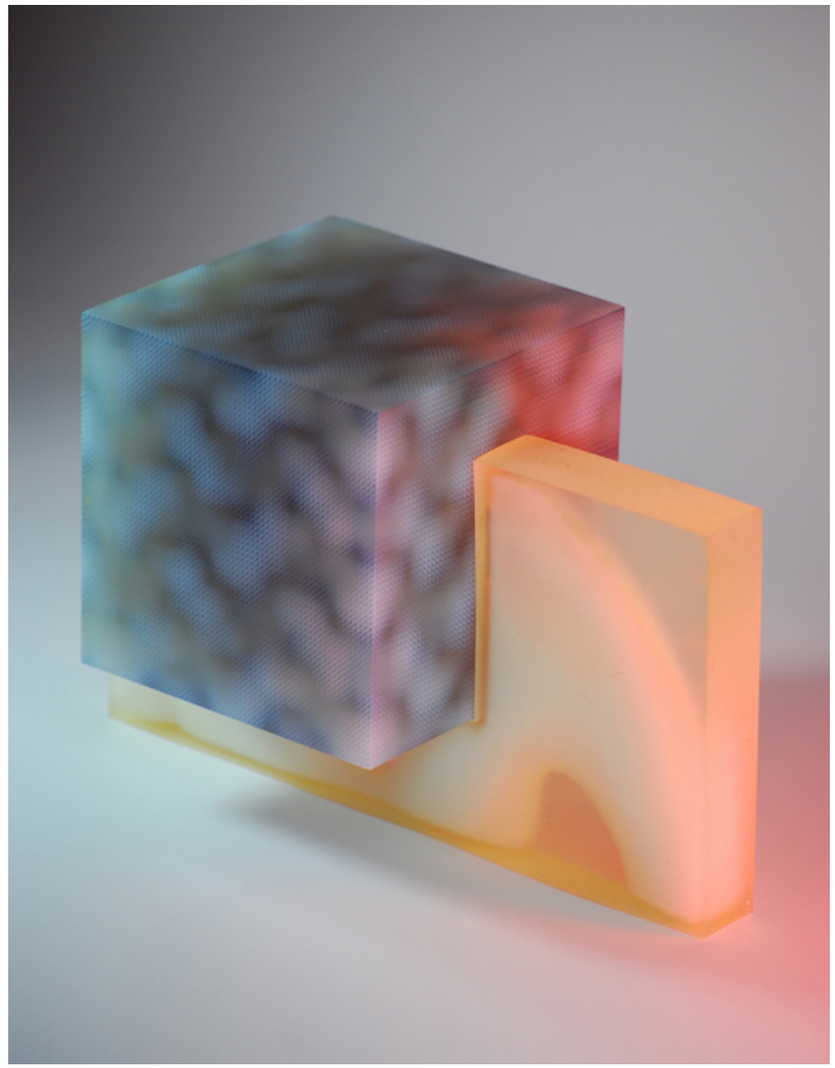
VOXELS



Volume

Information for every element

3D Printing



Voxel Grid Representation

- Primitive:

  voxel

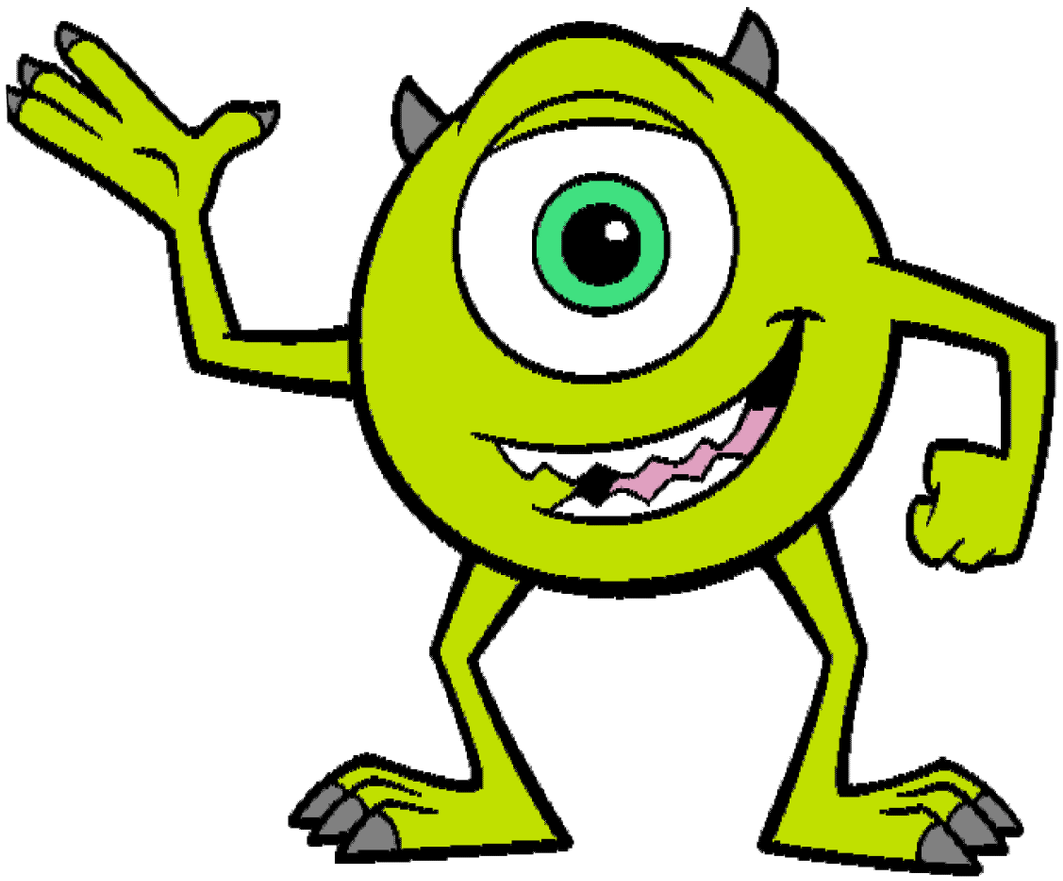
- Recipe:

  material to each voxel

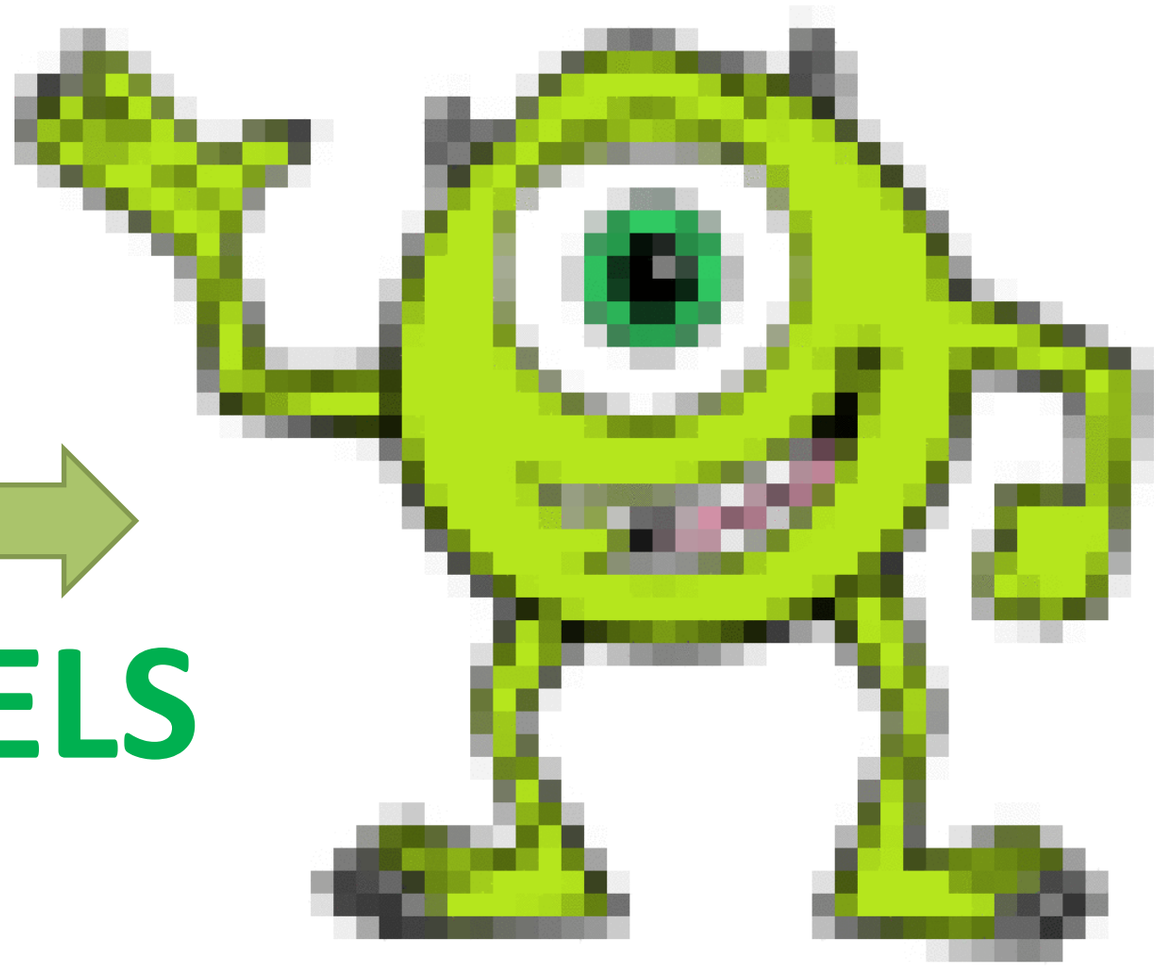
One down…

but let’s keep investigating!

Back to 2D

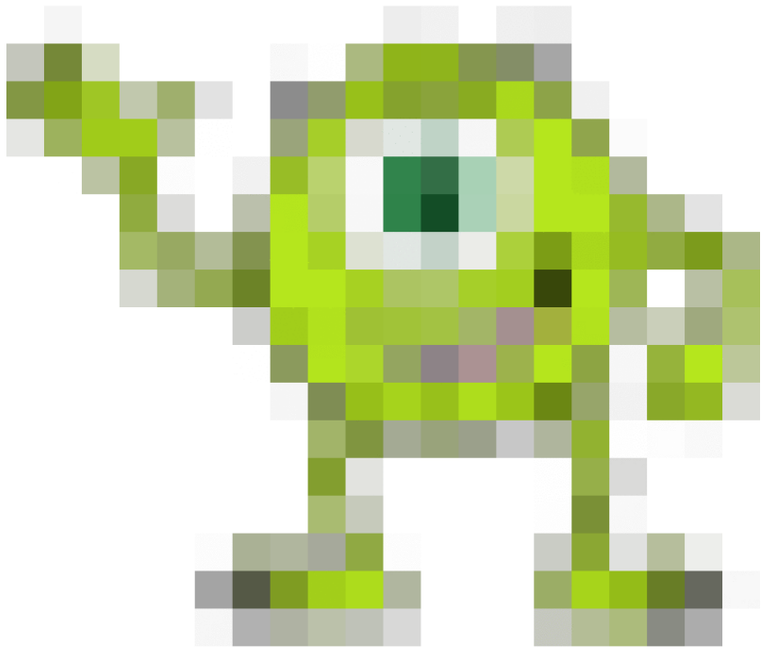


PIXELS

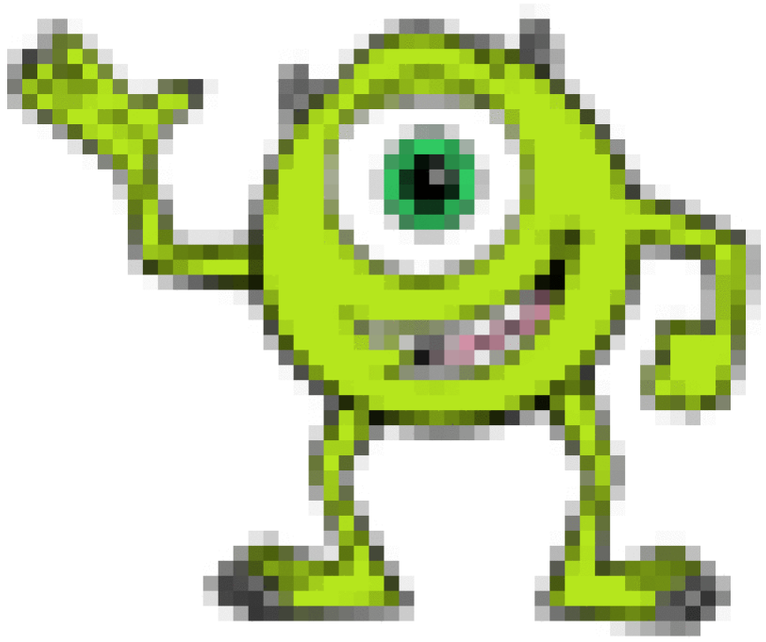


Back to 2D

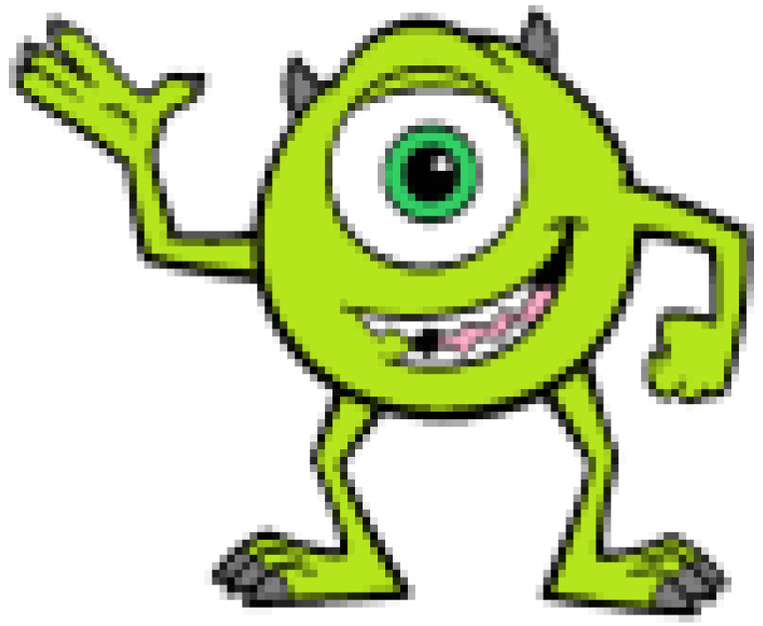
The Resolution Issue



20X20 Grid



50X50 Grid



100X100 Grid

The Resolution Issue in 3D

In 2D: NXN (N^2)

In 3D: NXNXN (N^3)

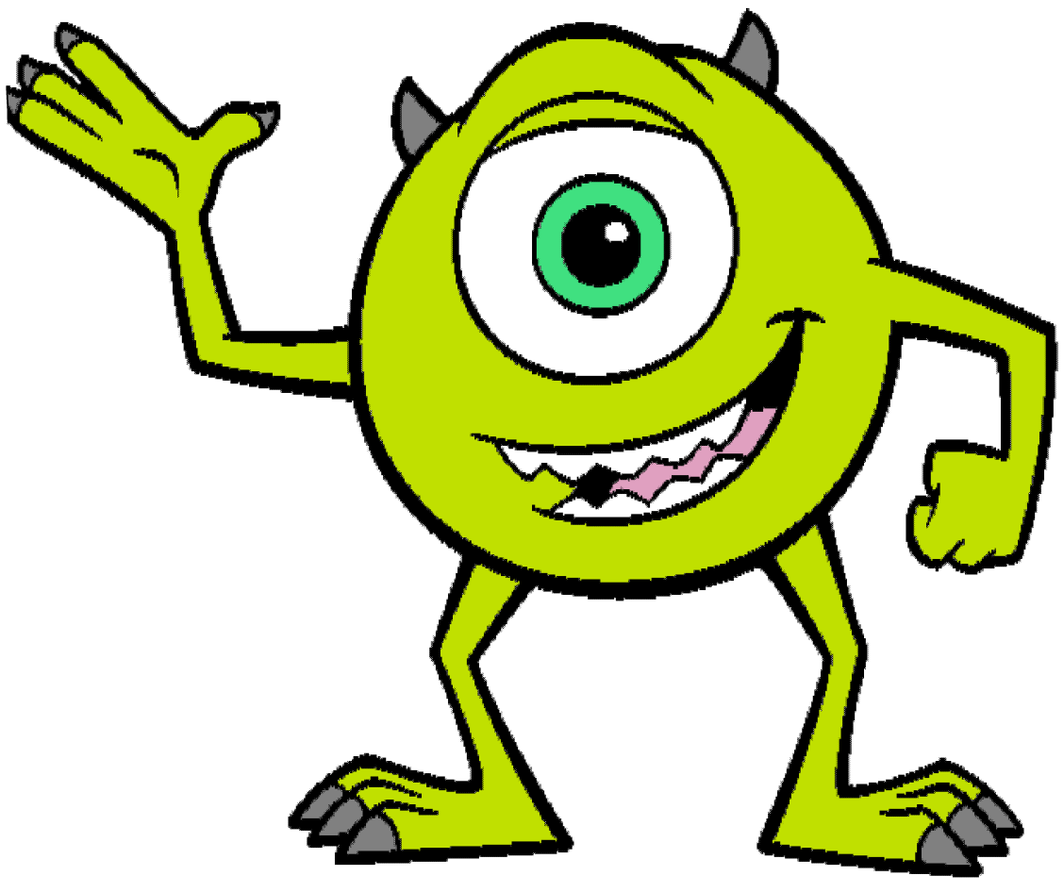
The Resolution Issue in 3D

In 2D: NXN (N^2)
In 3D: NXNXN (N^3)

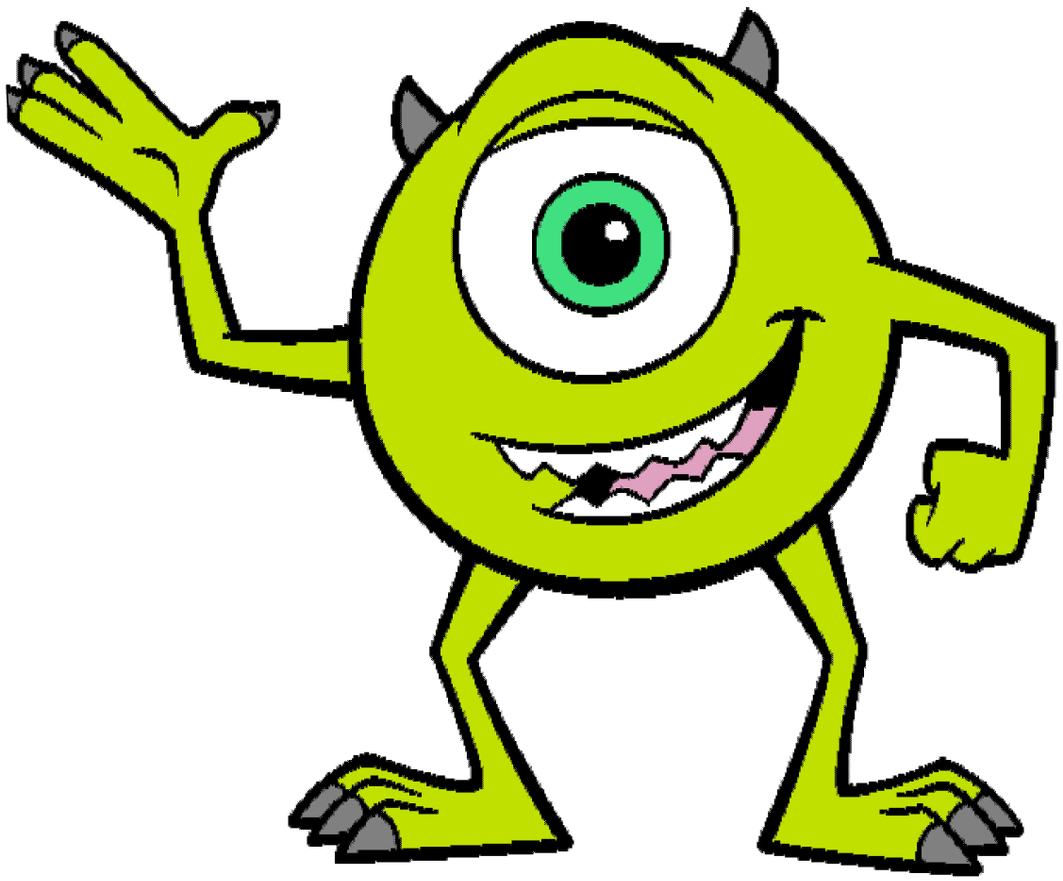
N = 10	100 pixels	1,000 voxels
N = 100	10,000 pixels	1,000,000 voxels

This does not scale well!!!! ☹

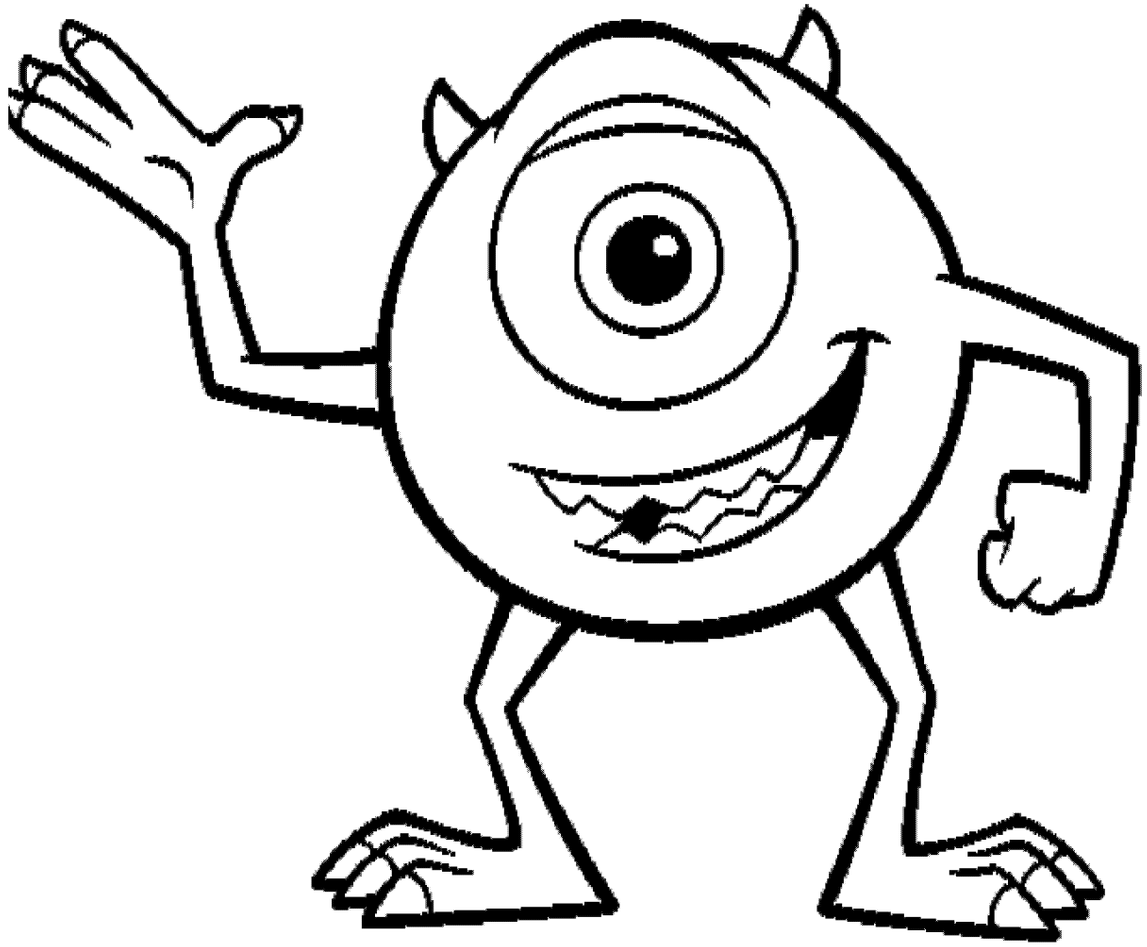
Think again in 2D



Think again in 2D

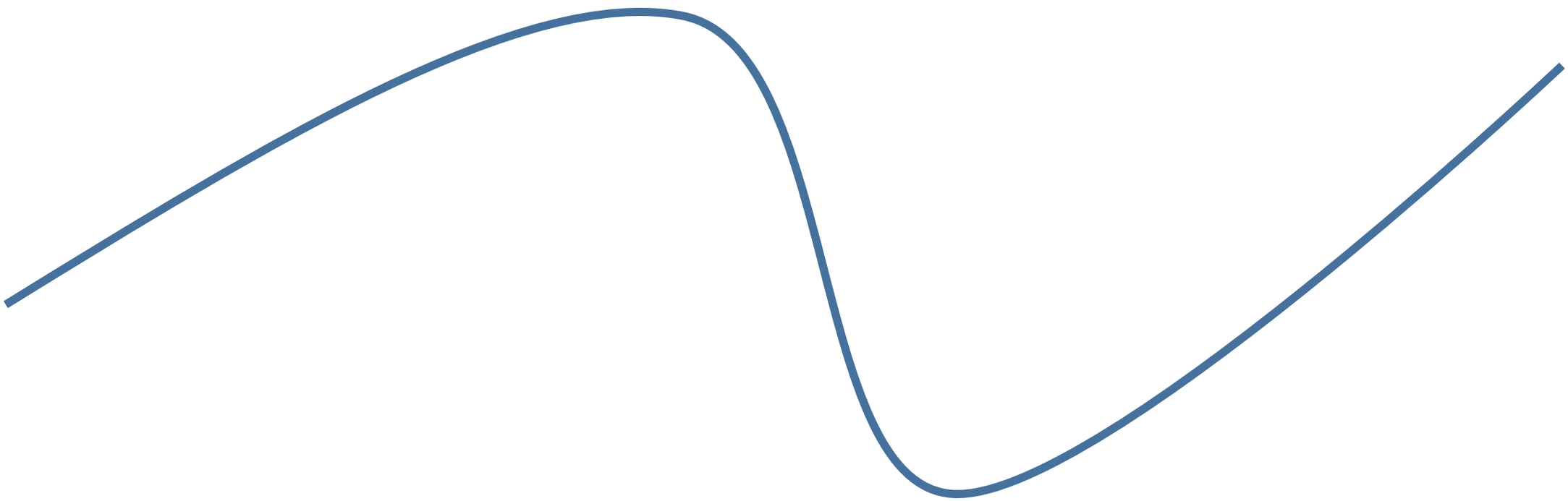


Instead of describing the area!

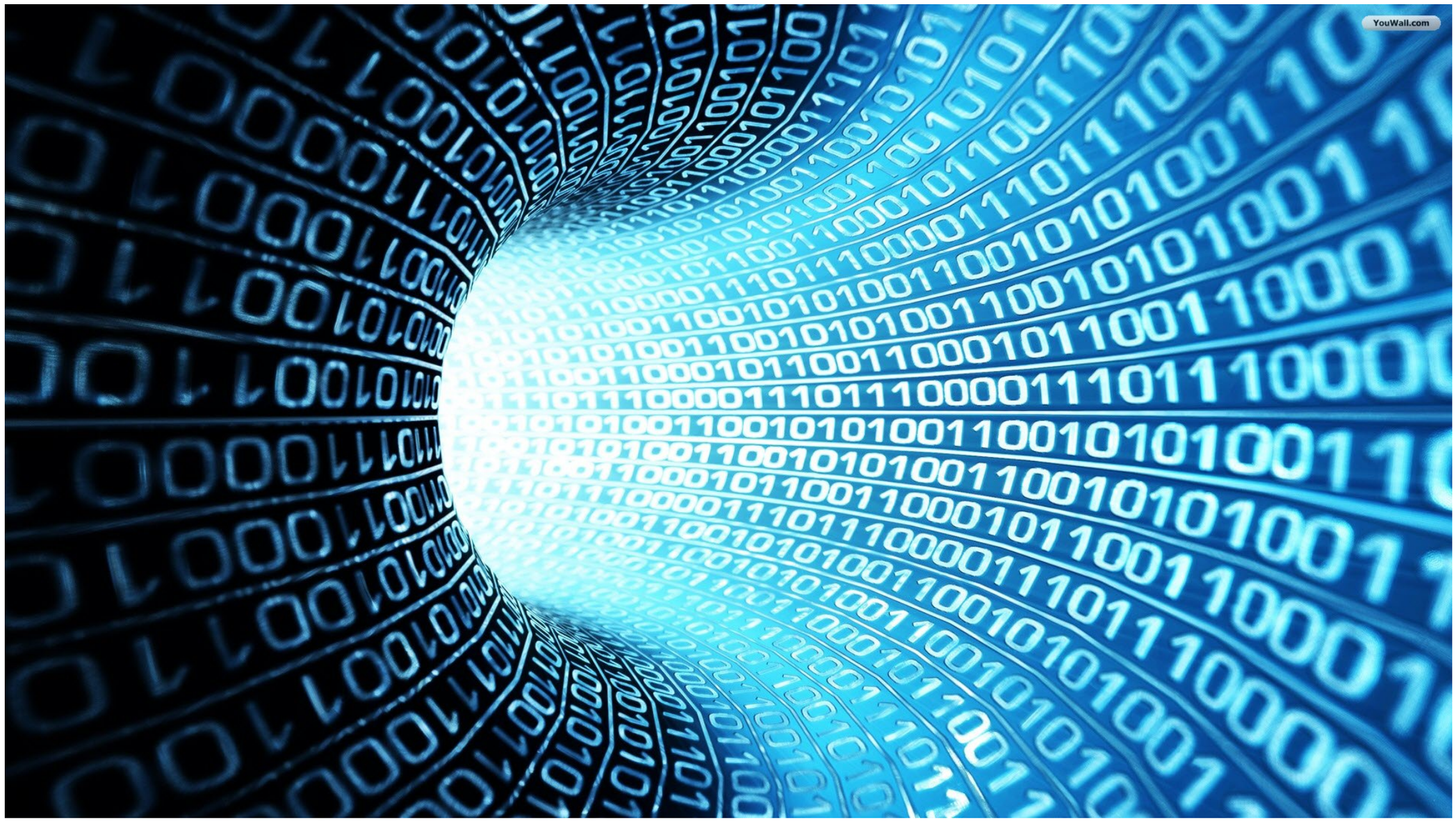


We can describe the boundary

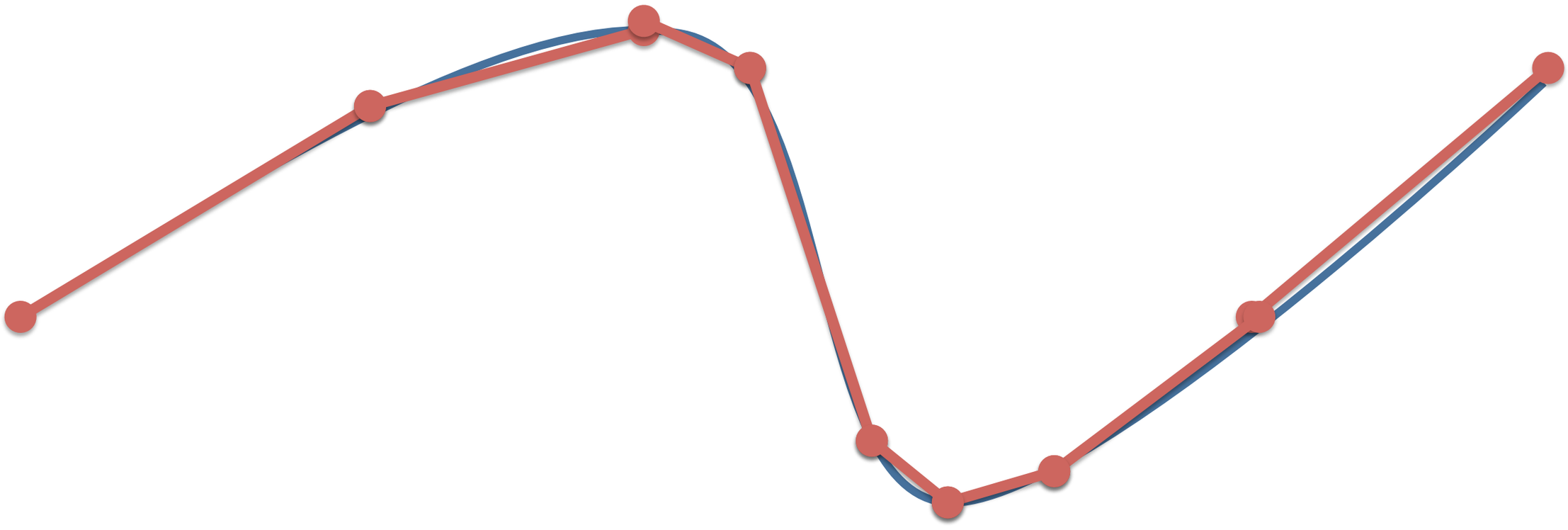
Curves



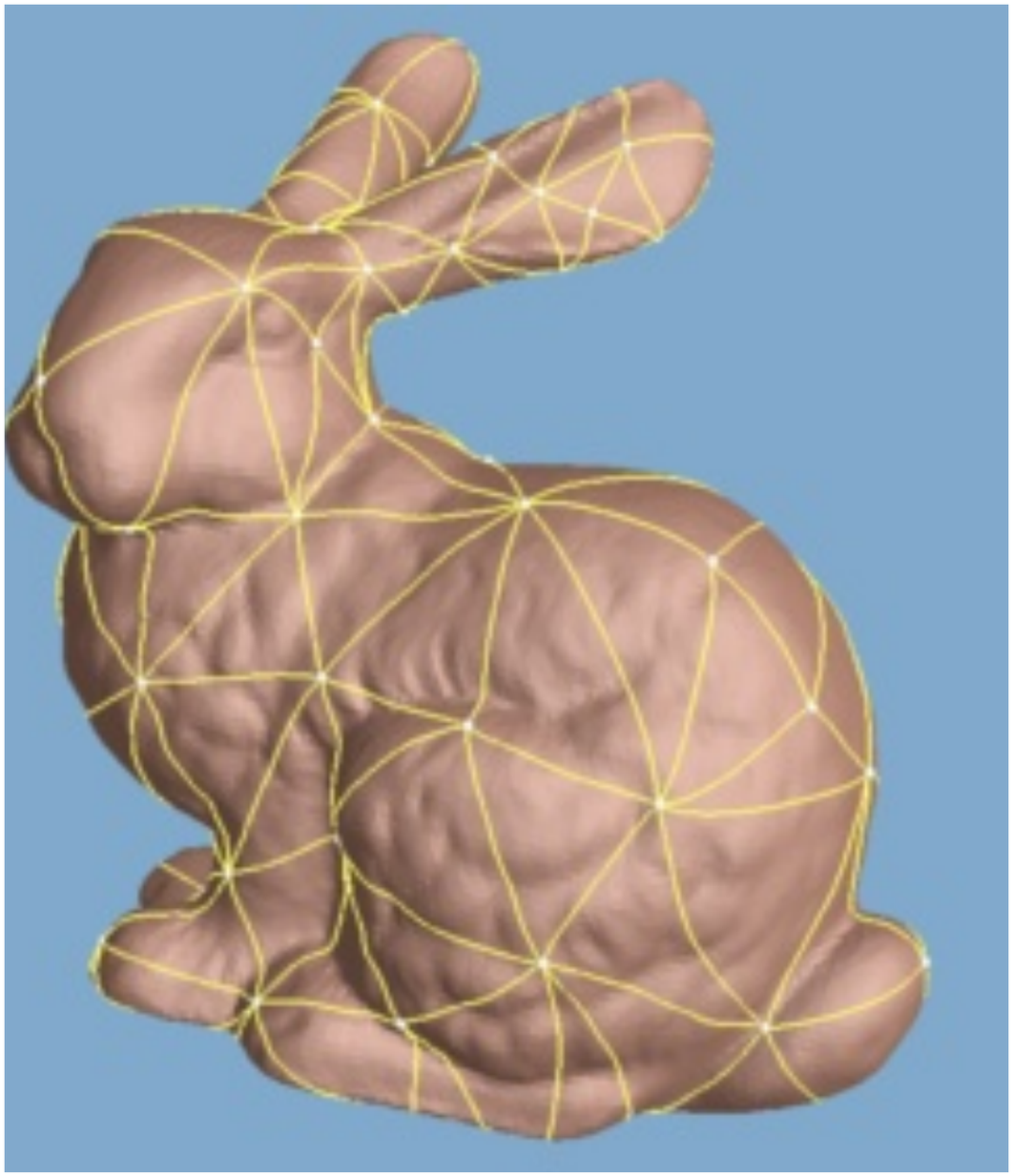
Discretization



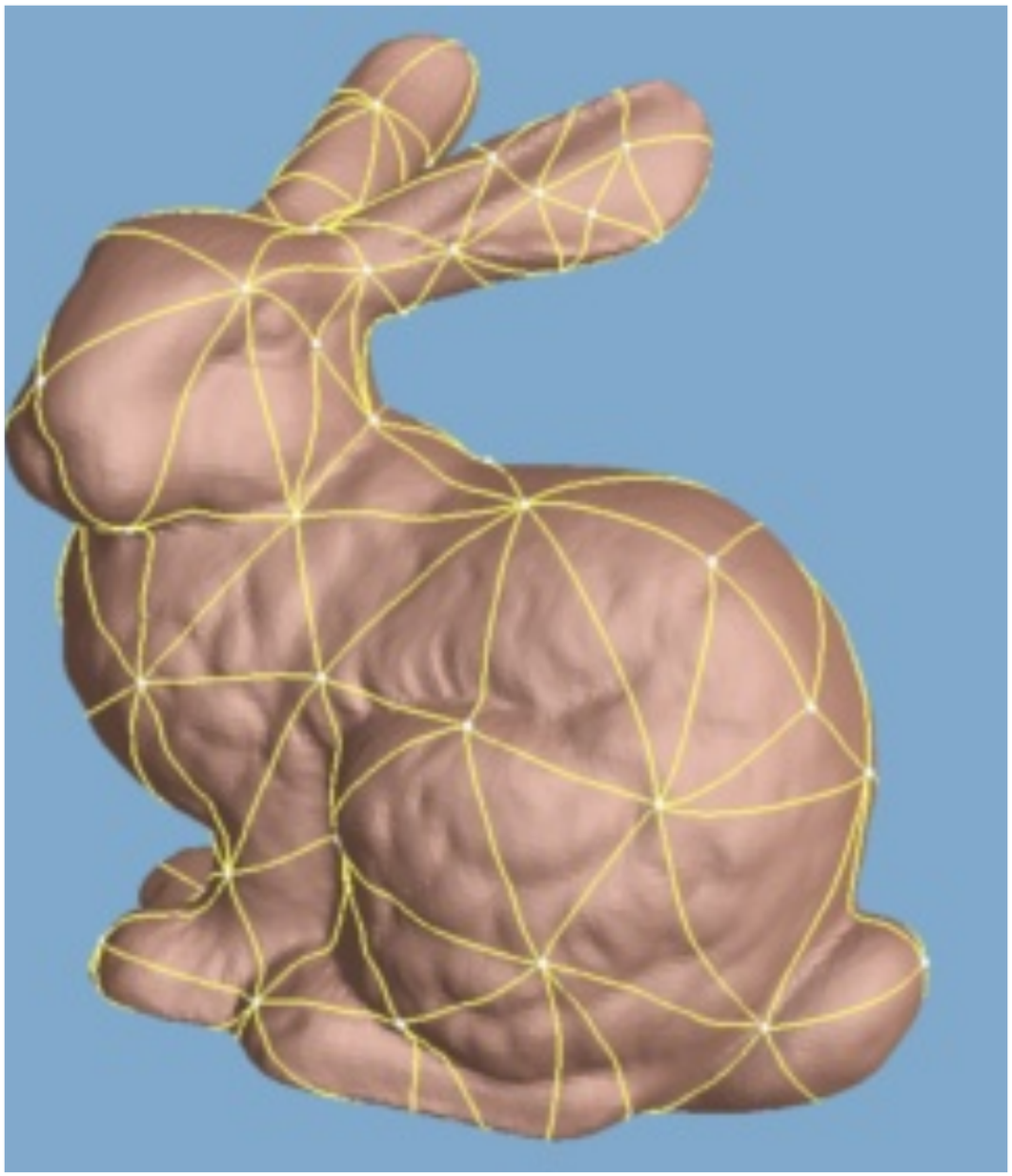
Curves

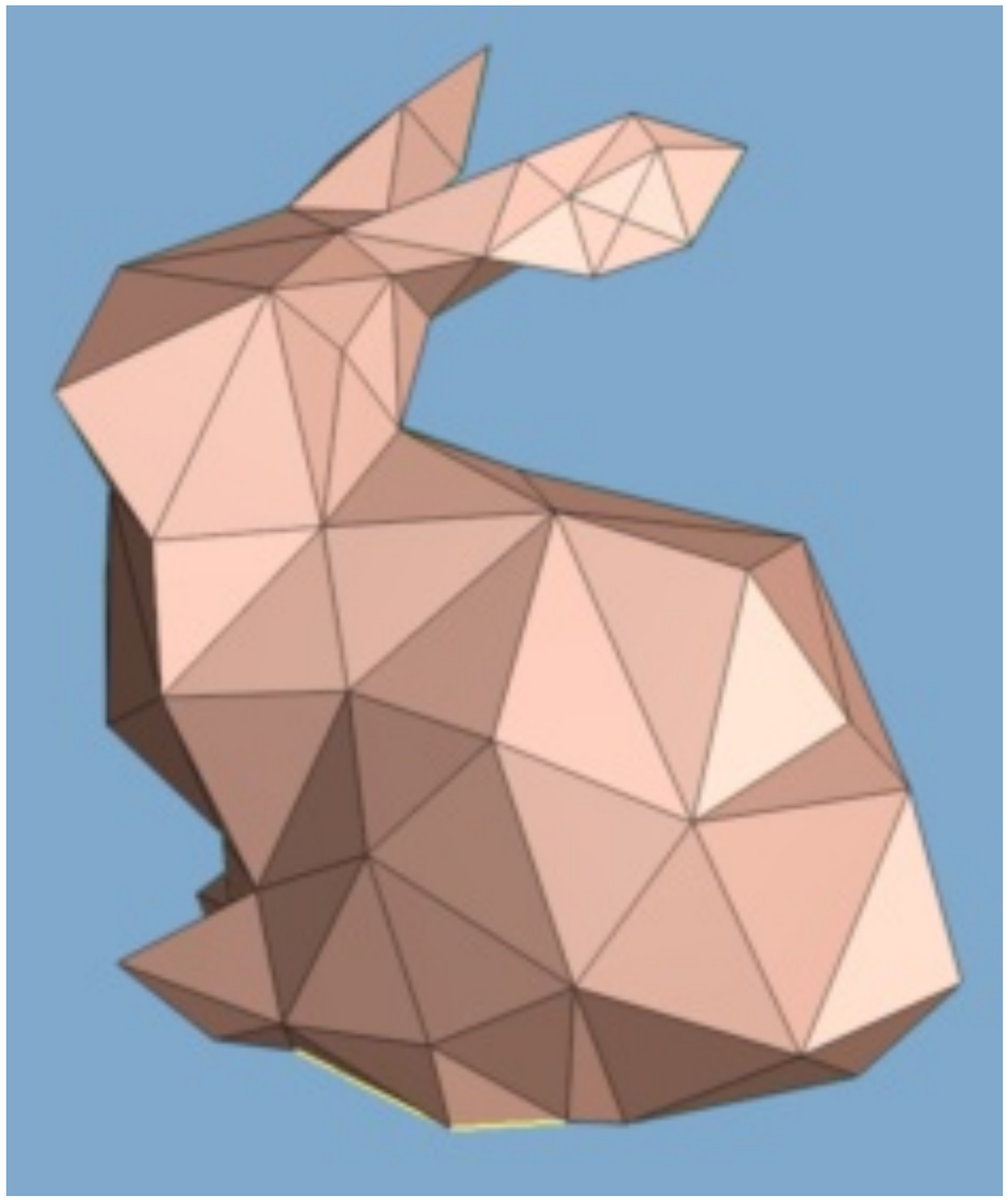


Surfaces



Surfaces





What is a Mesh?!?!?

Triangle Soup!

Mesh Representation

- Primitive:

  triangle

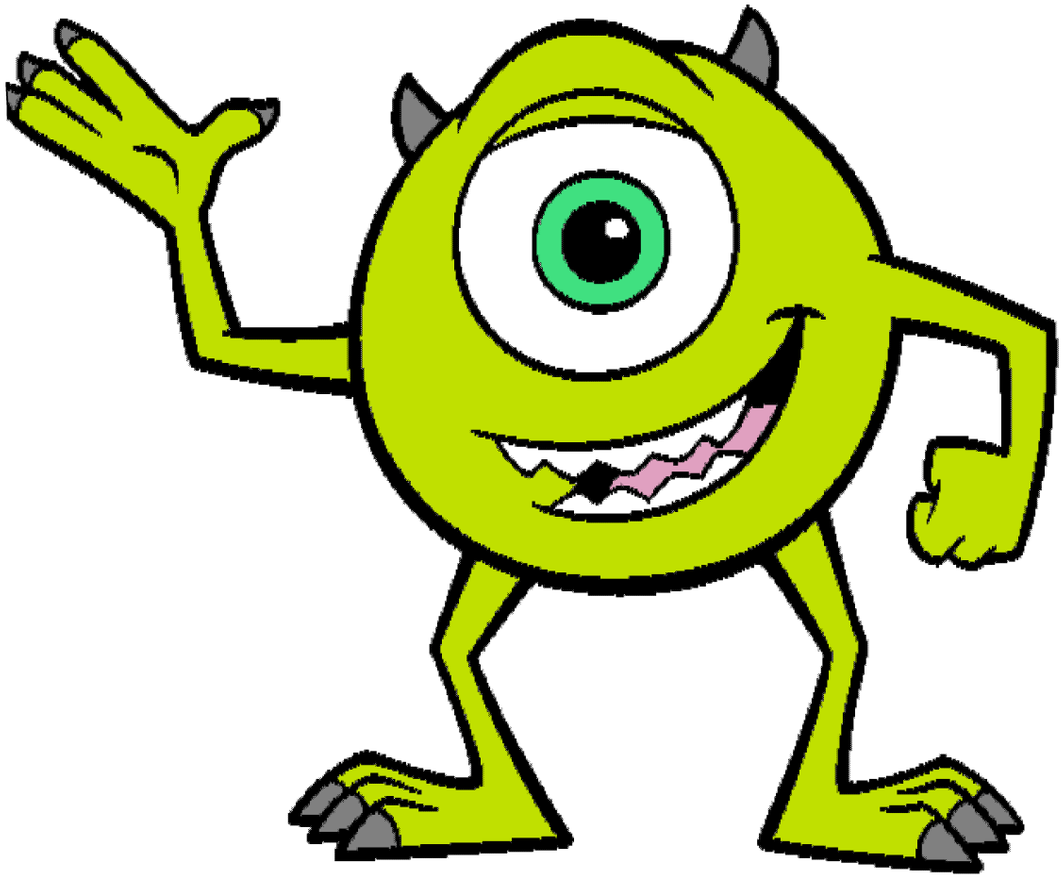
- Recipe:

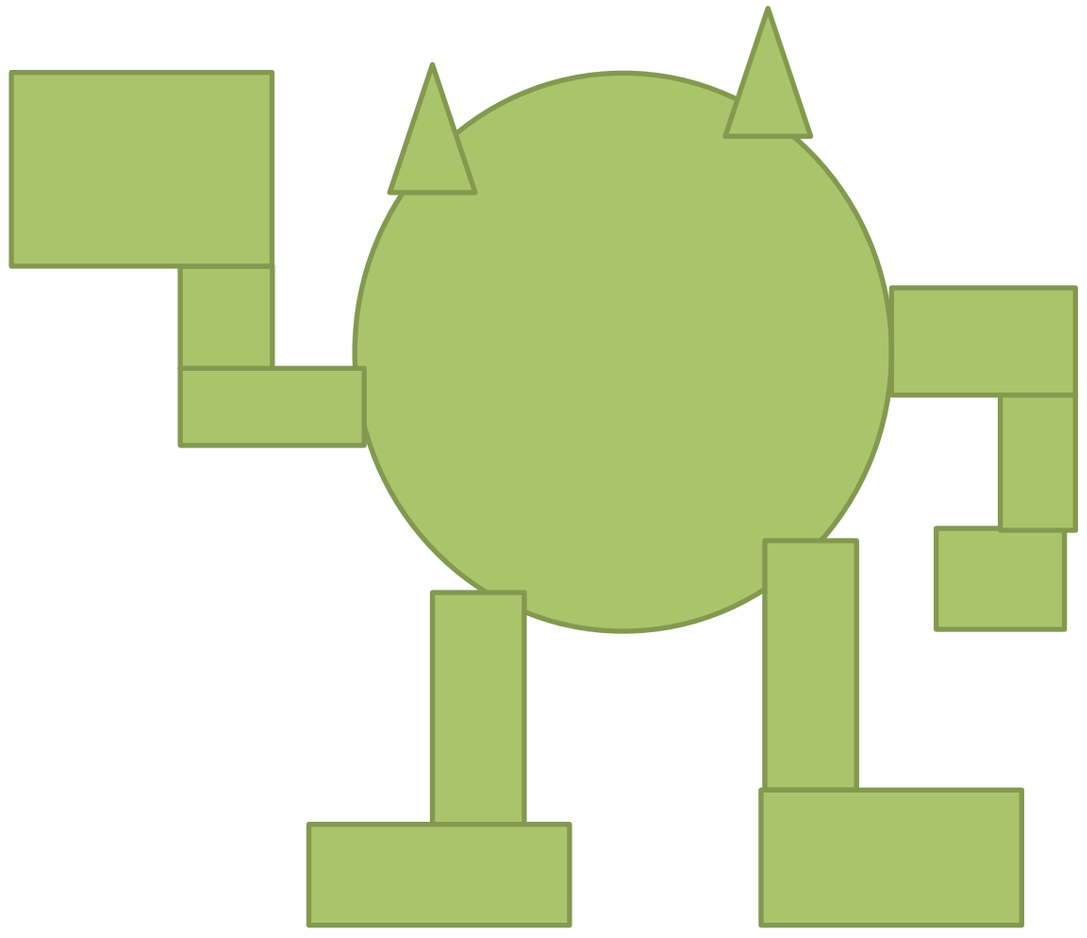
  list of triangles

Let’s open some up!

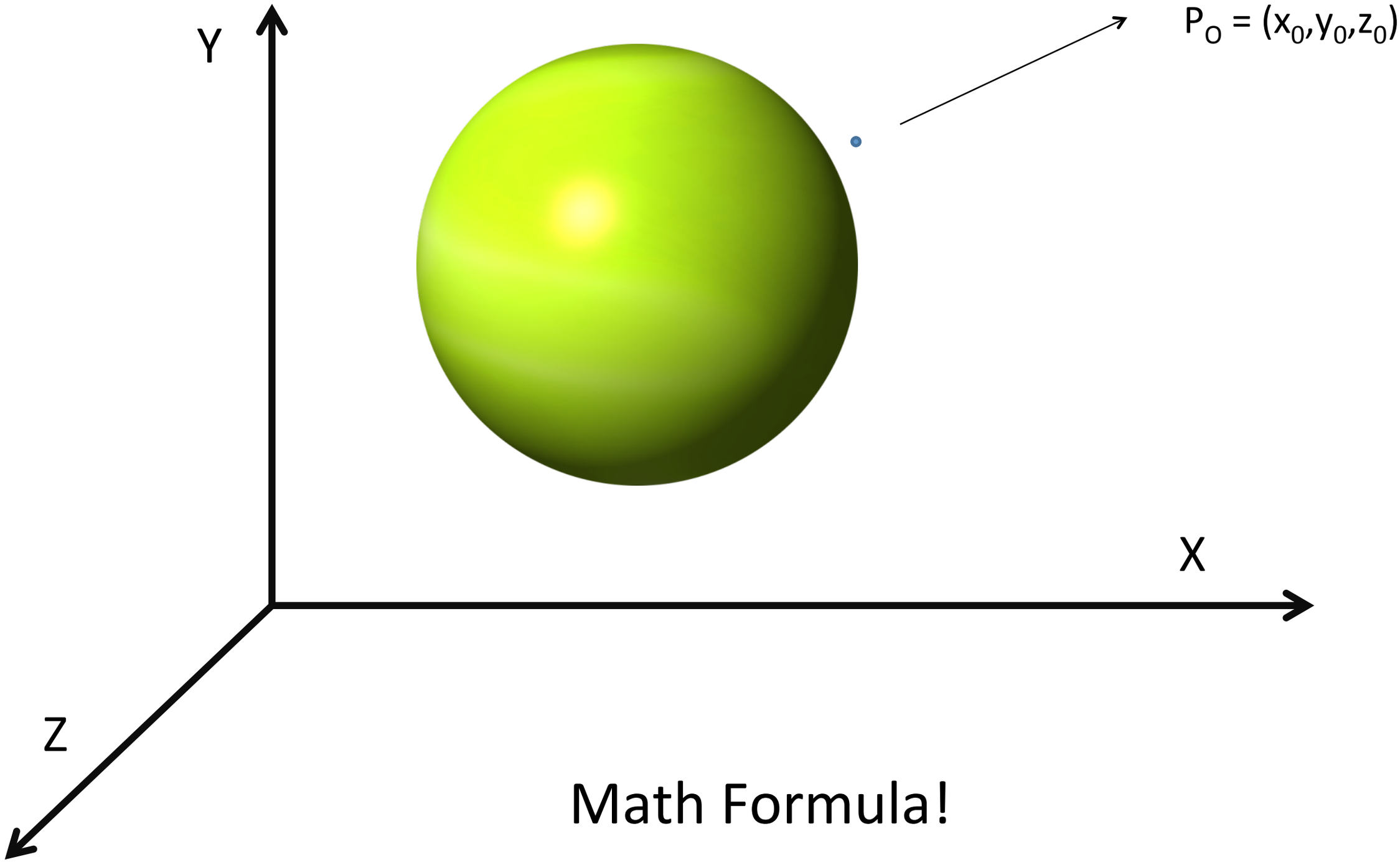
Two down…
ready for one more?

The third group of the activity



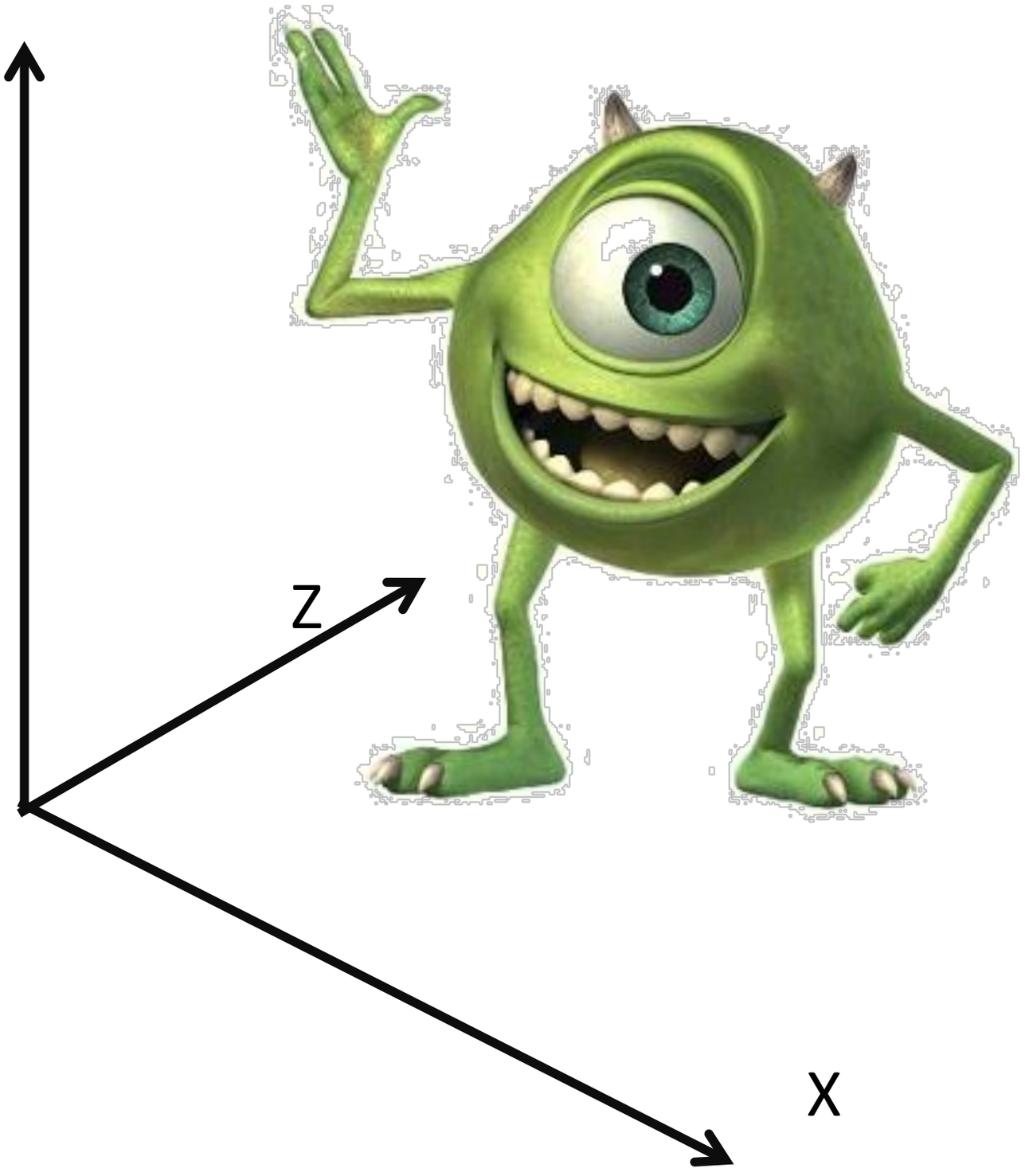


Simple Shapes

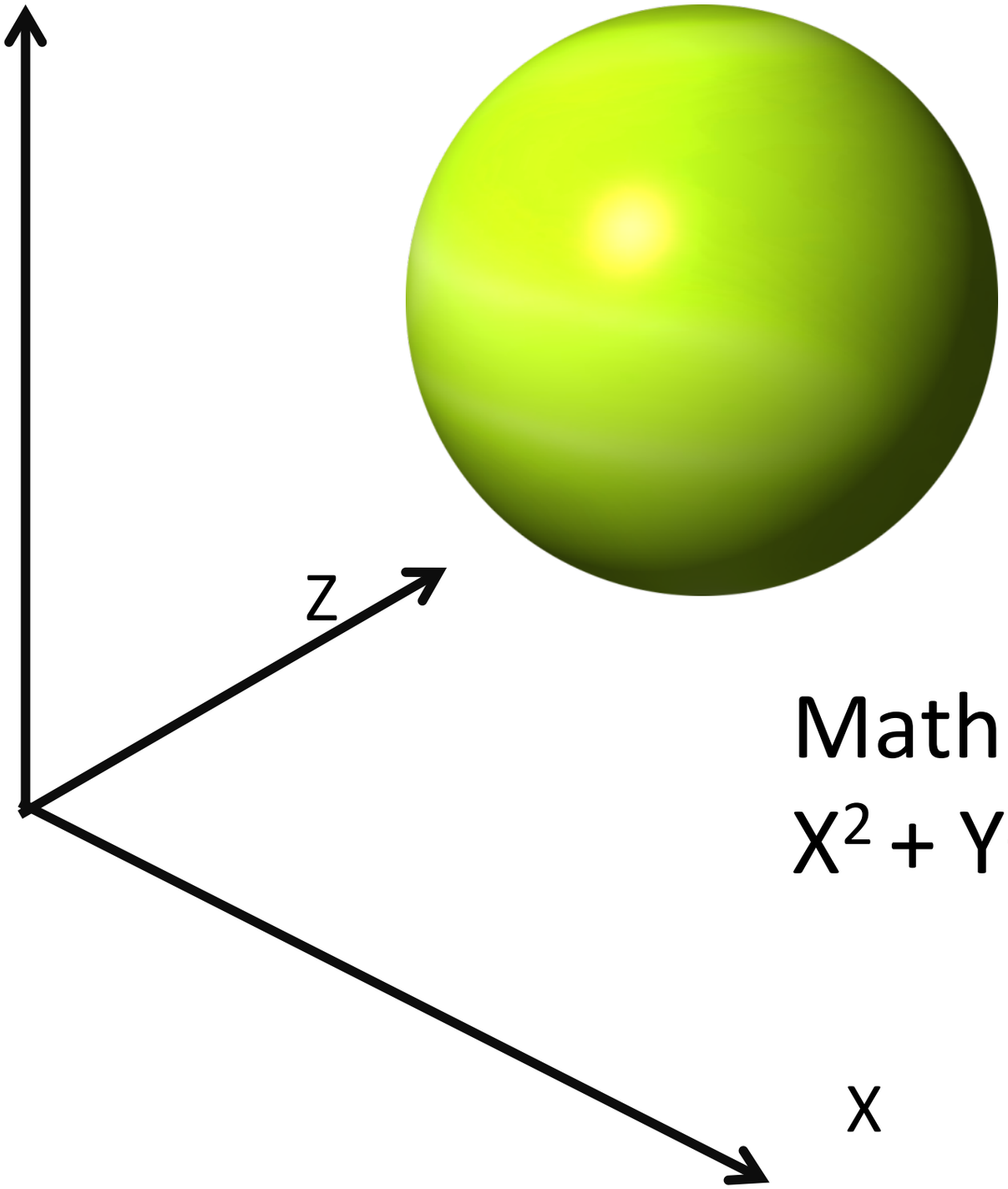


Math Formula!

How would you present this shape?



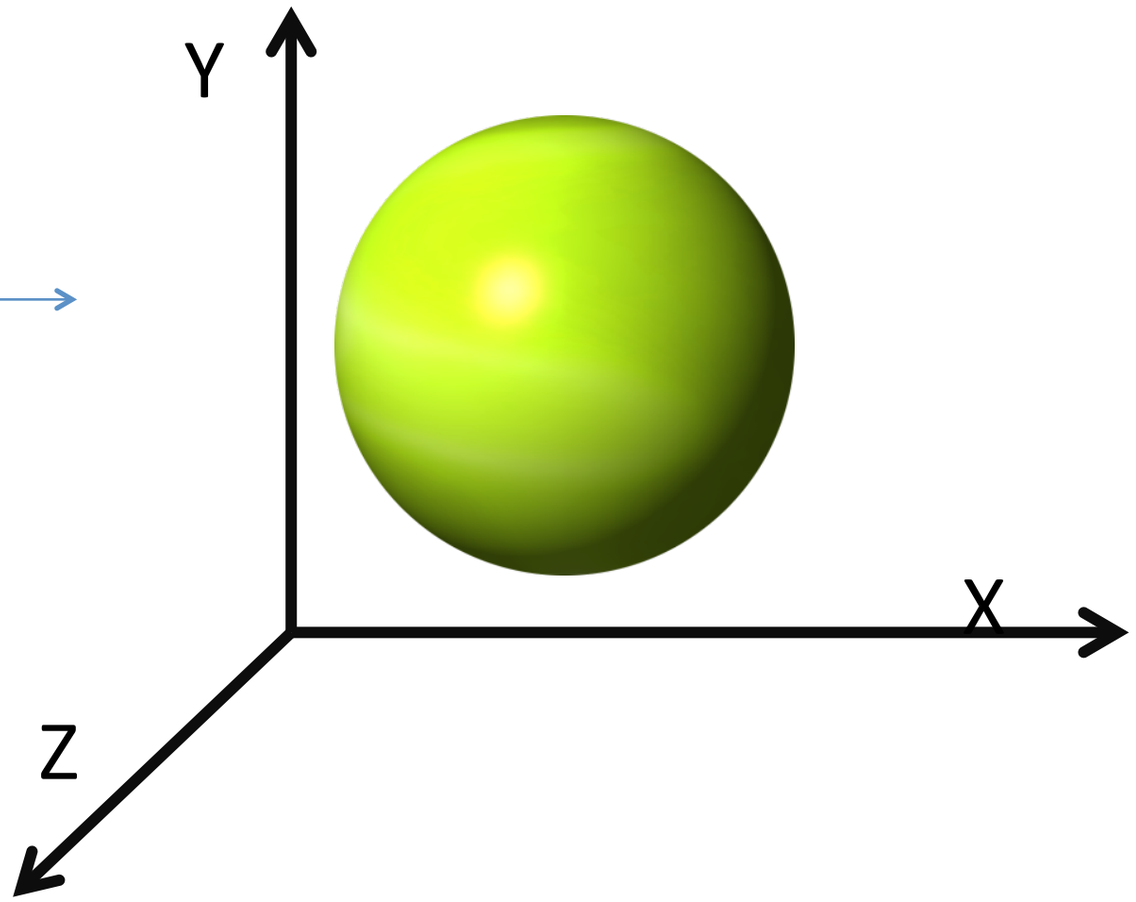
Simple Shapes



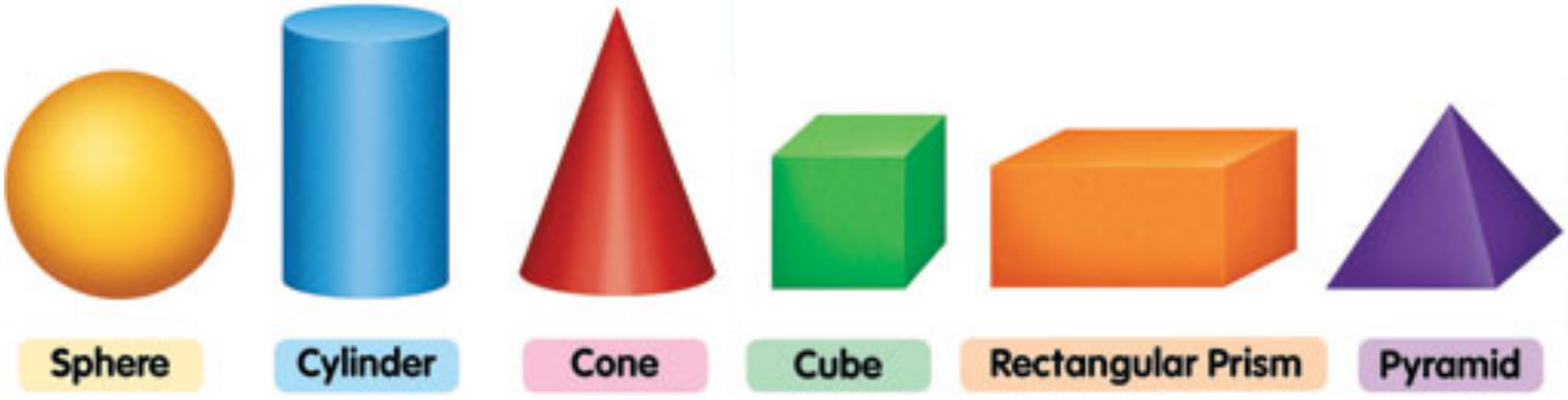
Math Formula!

$X^2 + Y^2 + Z^2 = R^2$

Now your computer can draw!



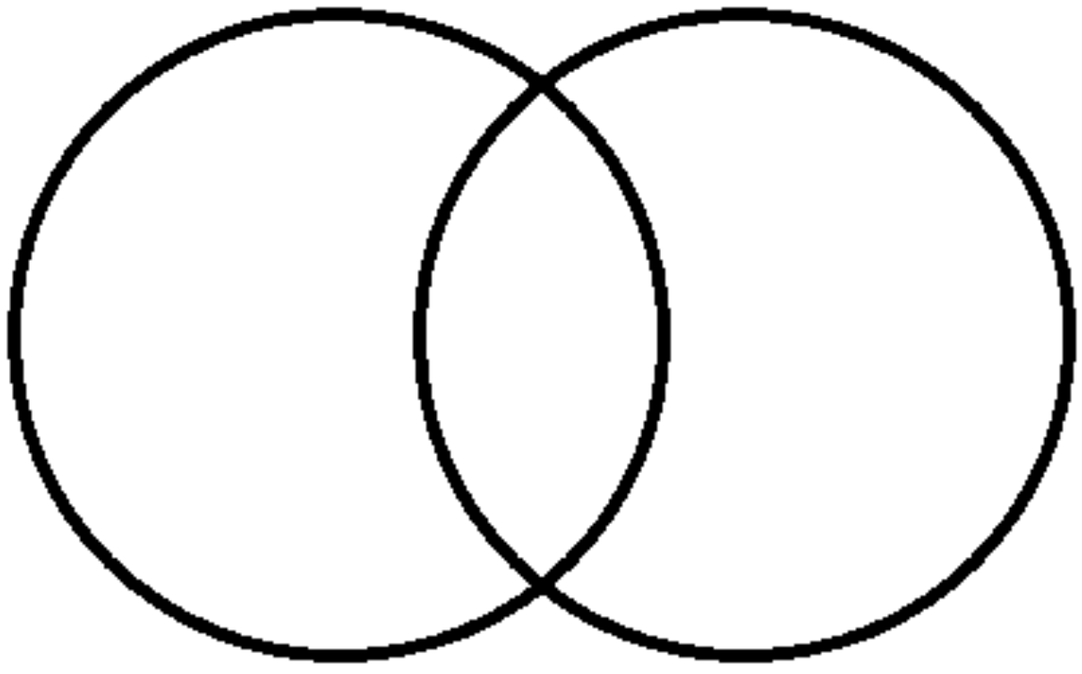
Library of Simple Shapes



But there’s not much one can do with simple shapes….
or is there?

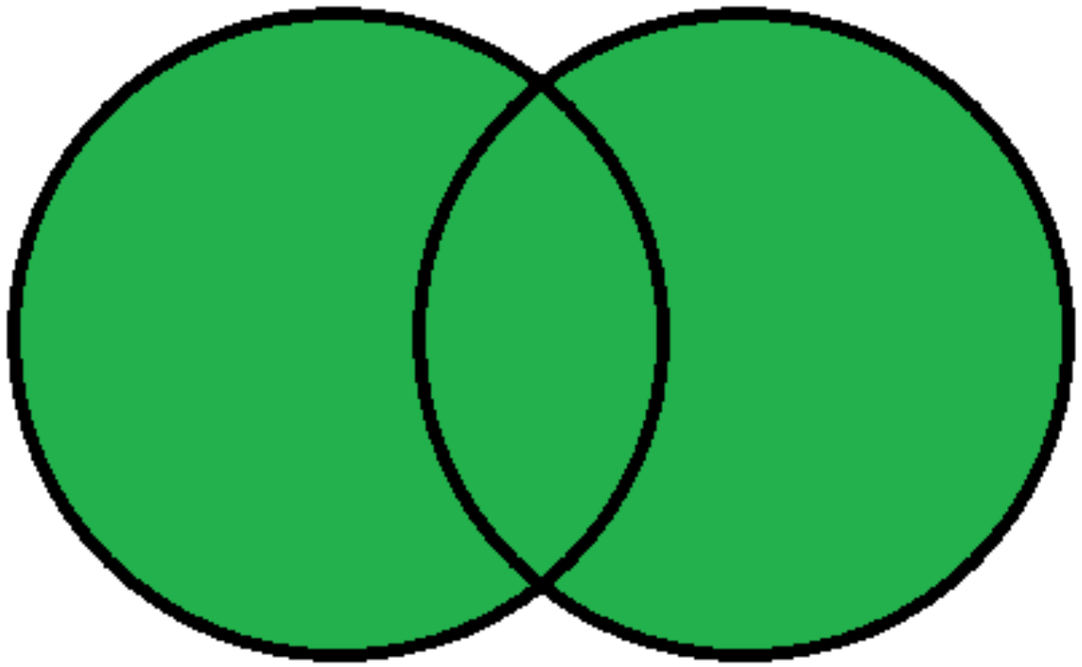
Mixing and Matching

Union



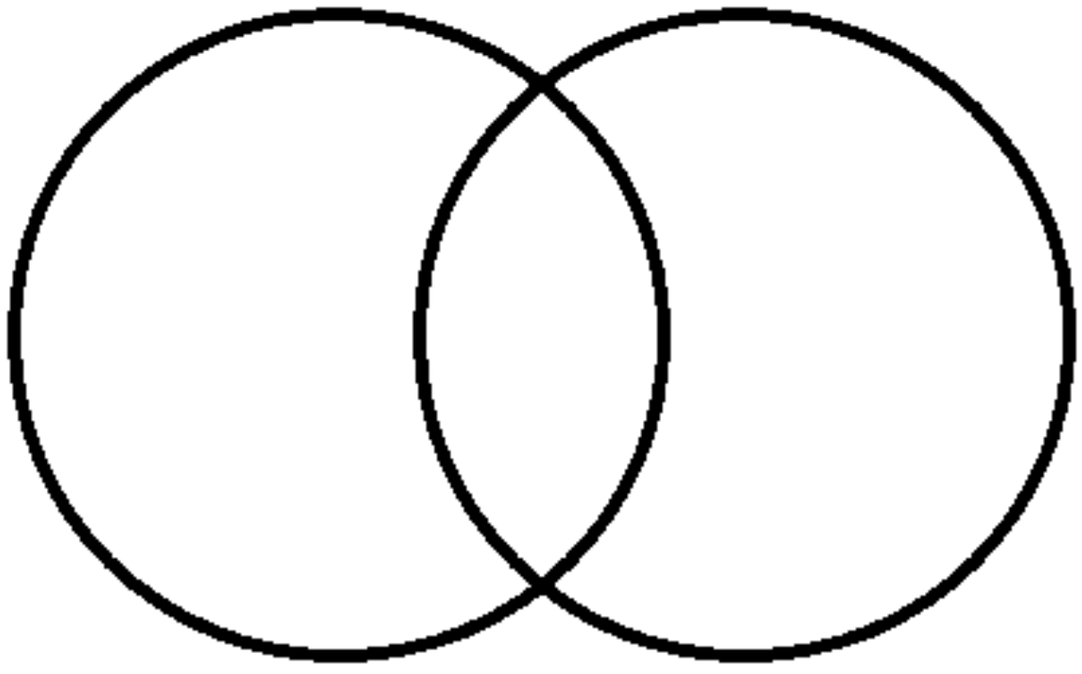
Mixing and Matching

Union



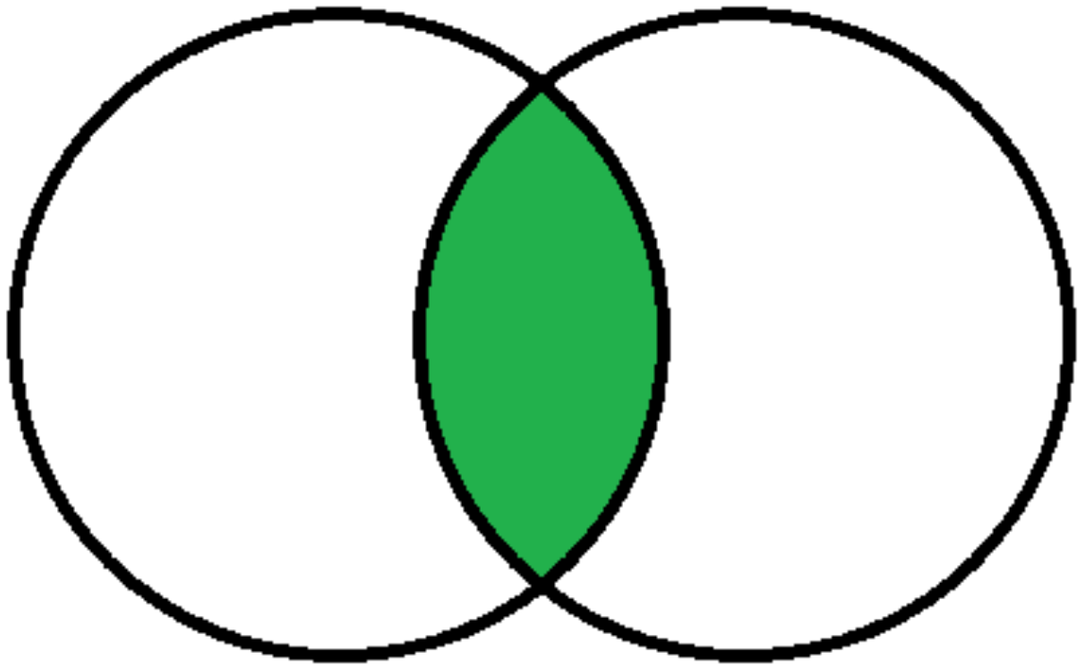
Mixing and Matching

Intersection



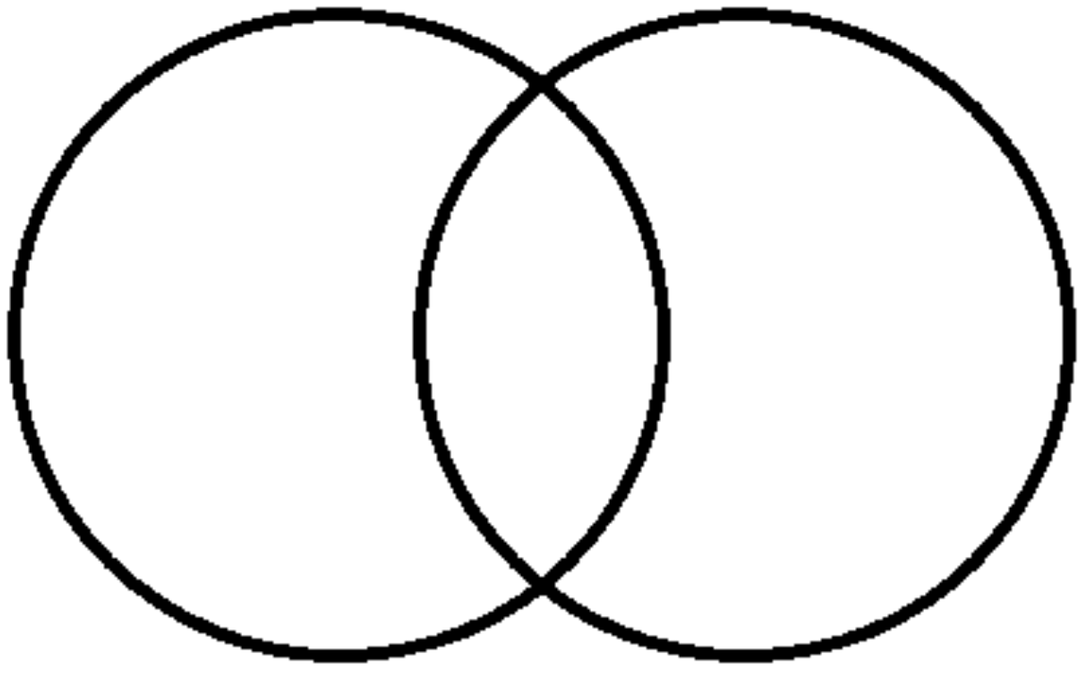
Mixing and Matching

Intersection



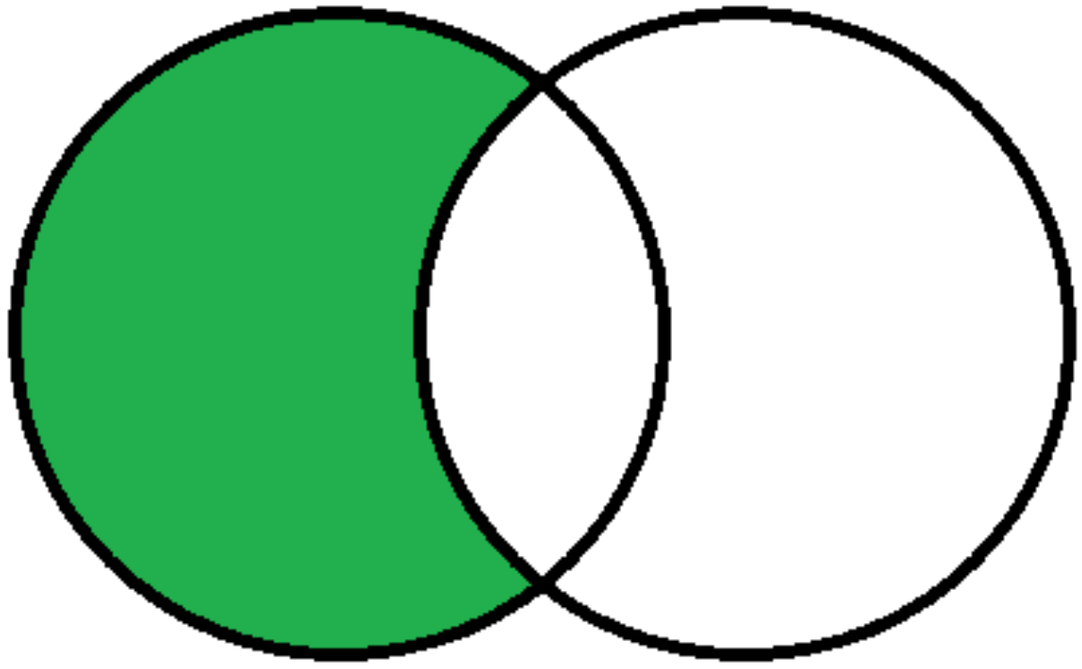
Mixing and Matching

Difference

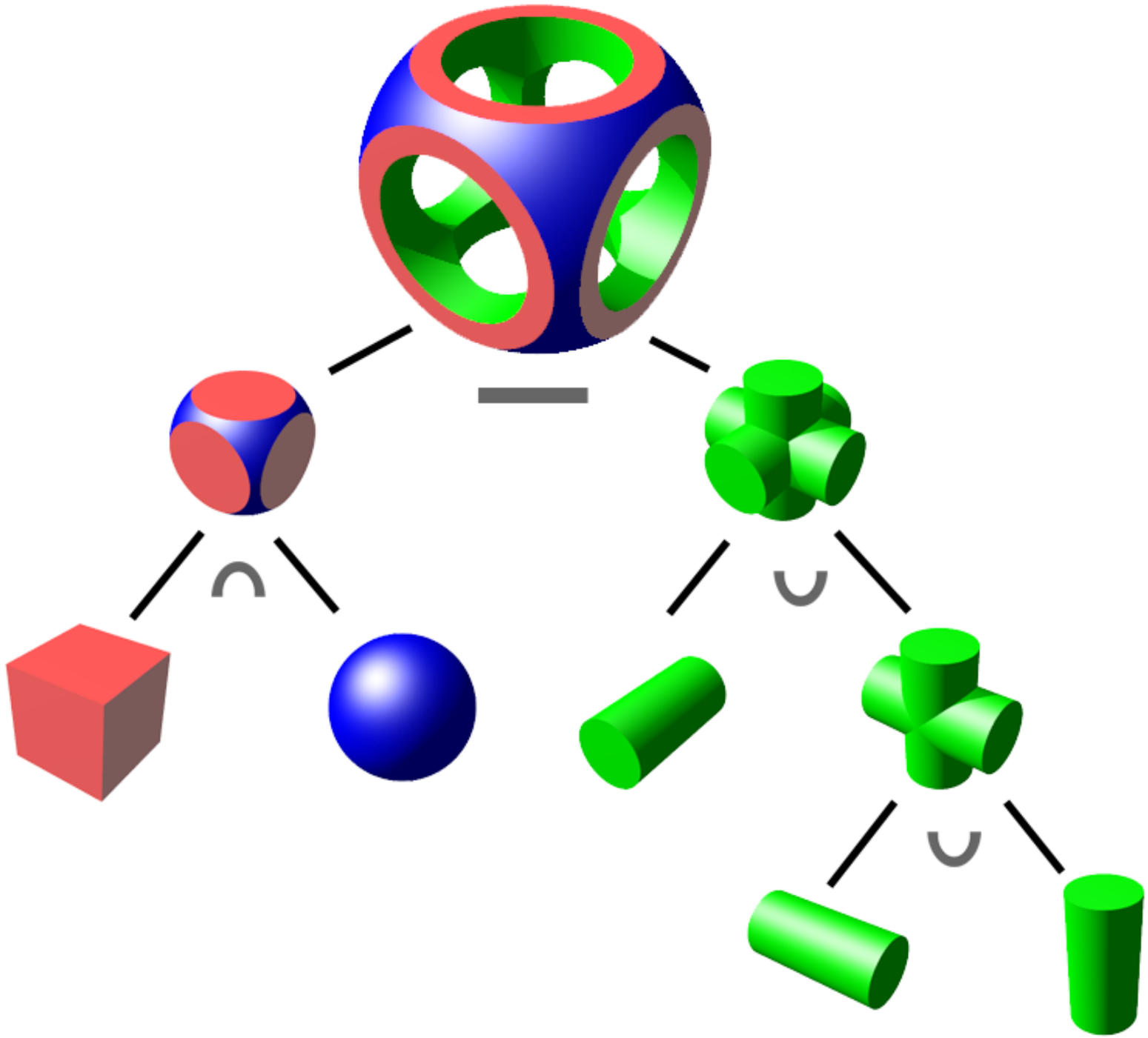


Mixing and Matching

Difference

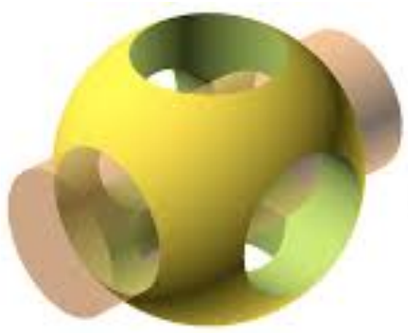


Constructive Solid Geometry

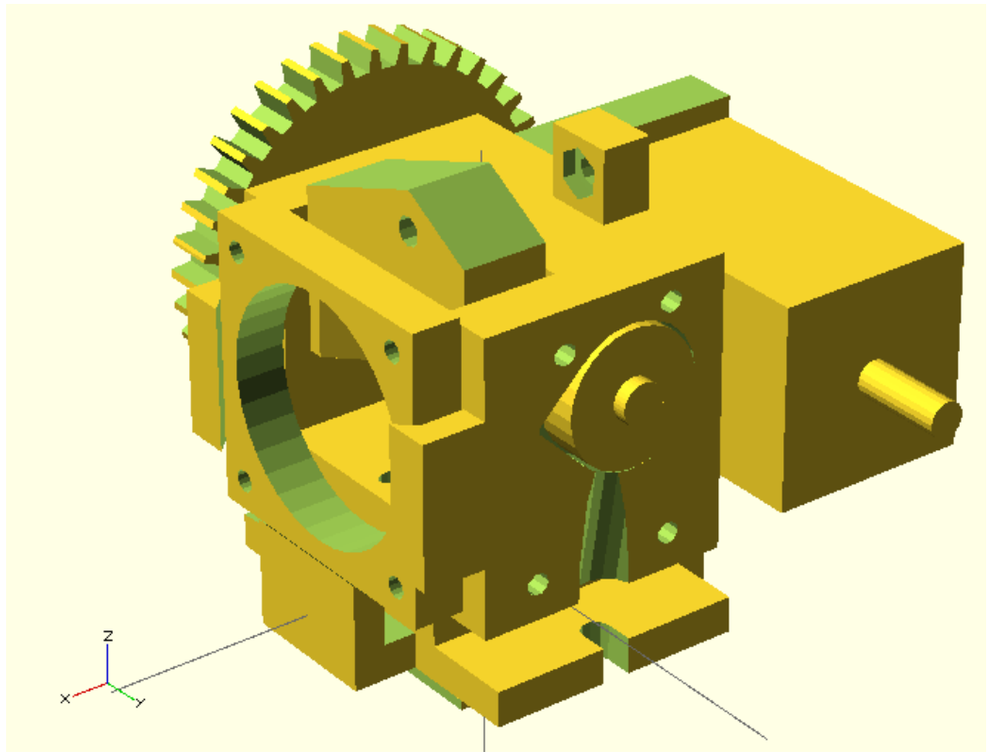


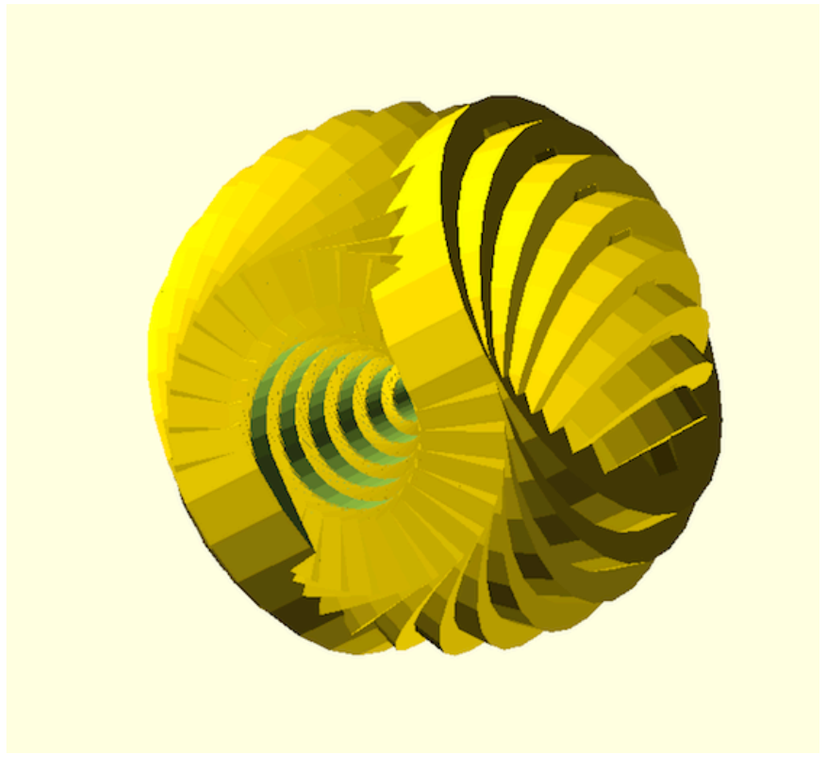
Constructive Solid Geometry

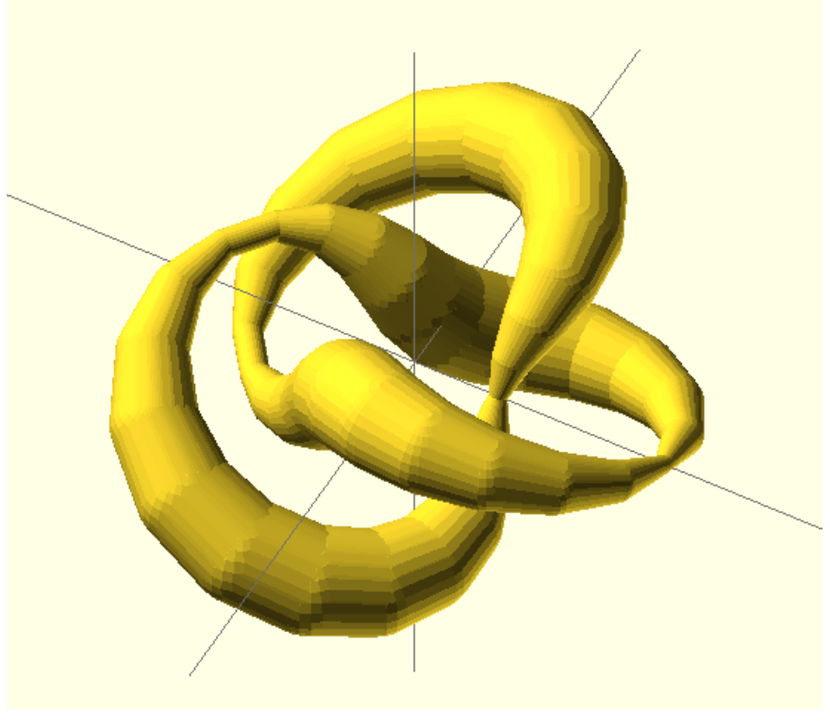
Demo:



Examples







CSG Representation

- Primitive:

  basic shapes

- Recipe:

  union, intersection, diff

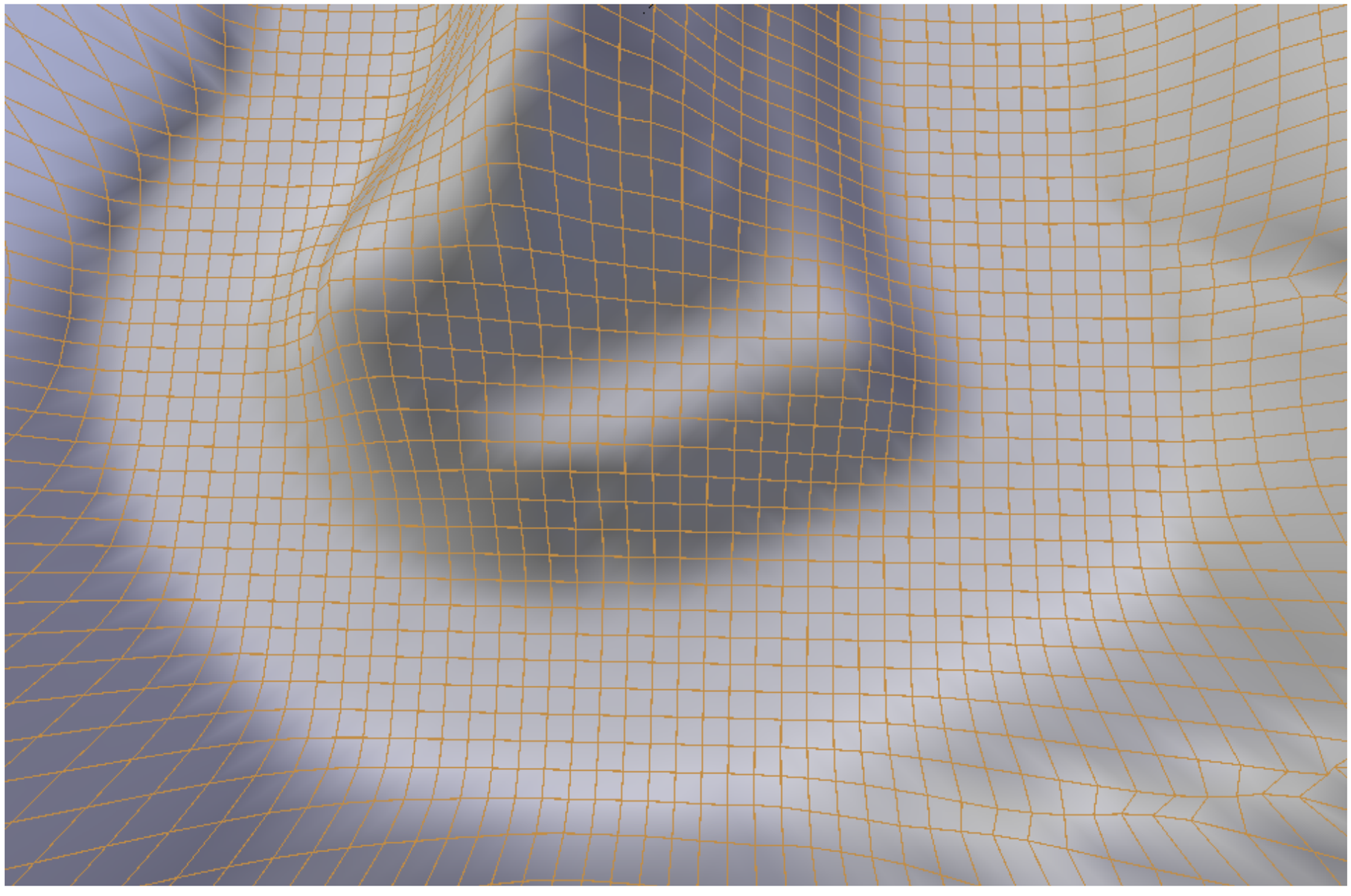
  etc …

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!

They are free!

Presented by Valentina Shin

REPRESENTING 3D SHAPES (II)

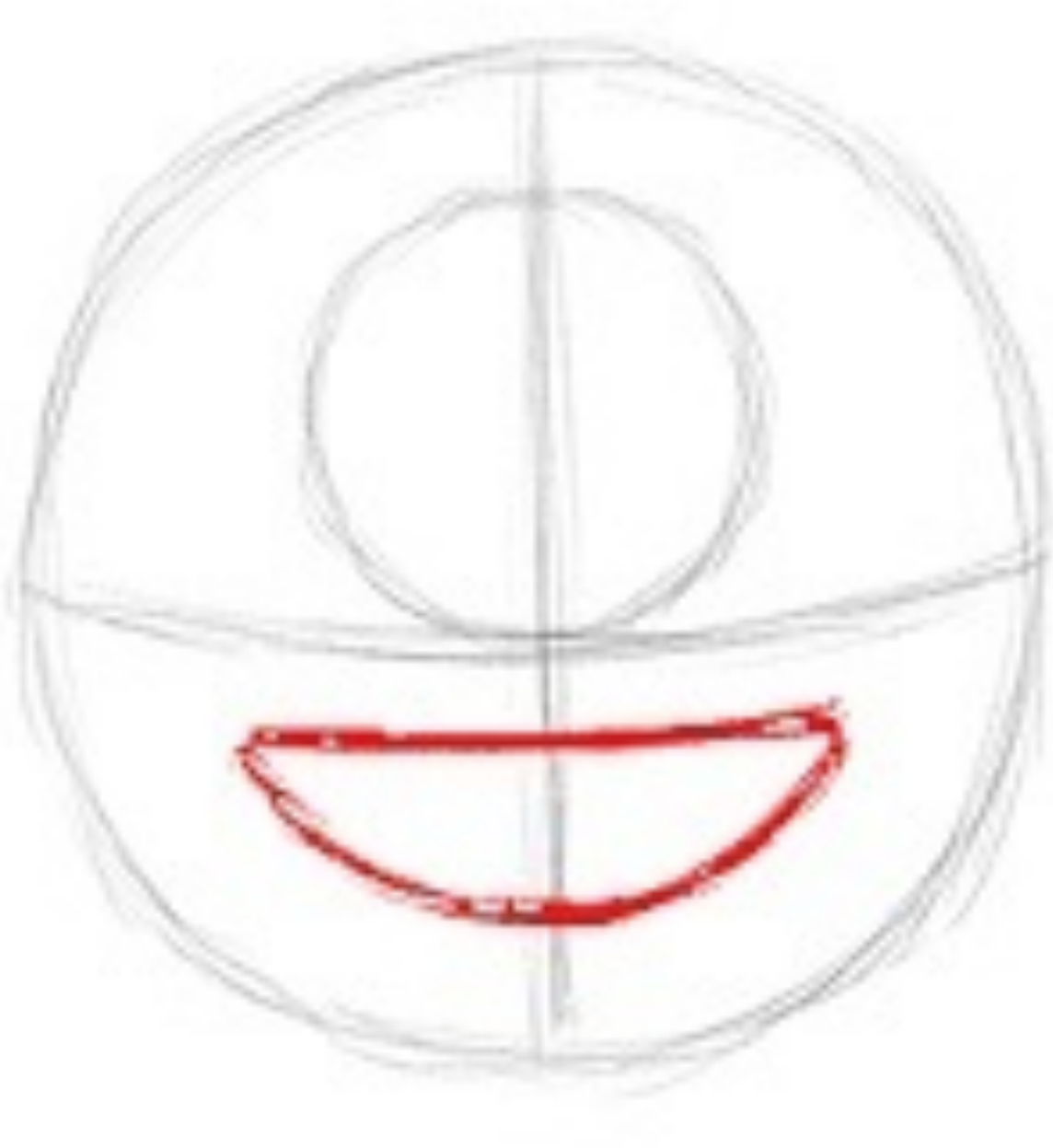
-PROCEDURAL MODELING

Pull out a piece of paper.

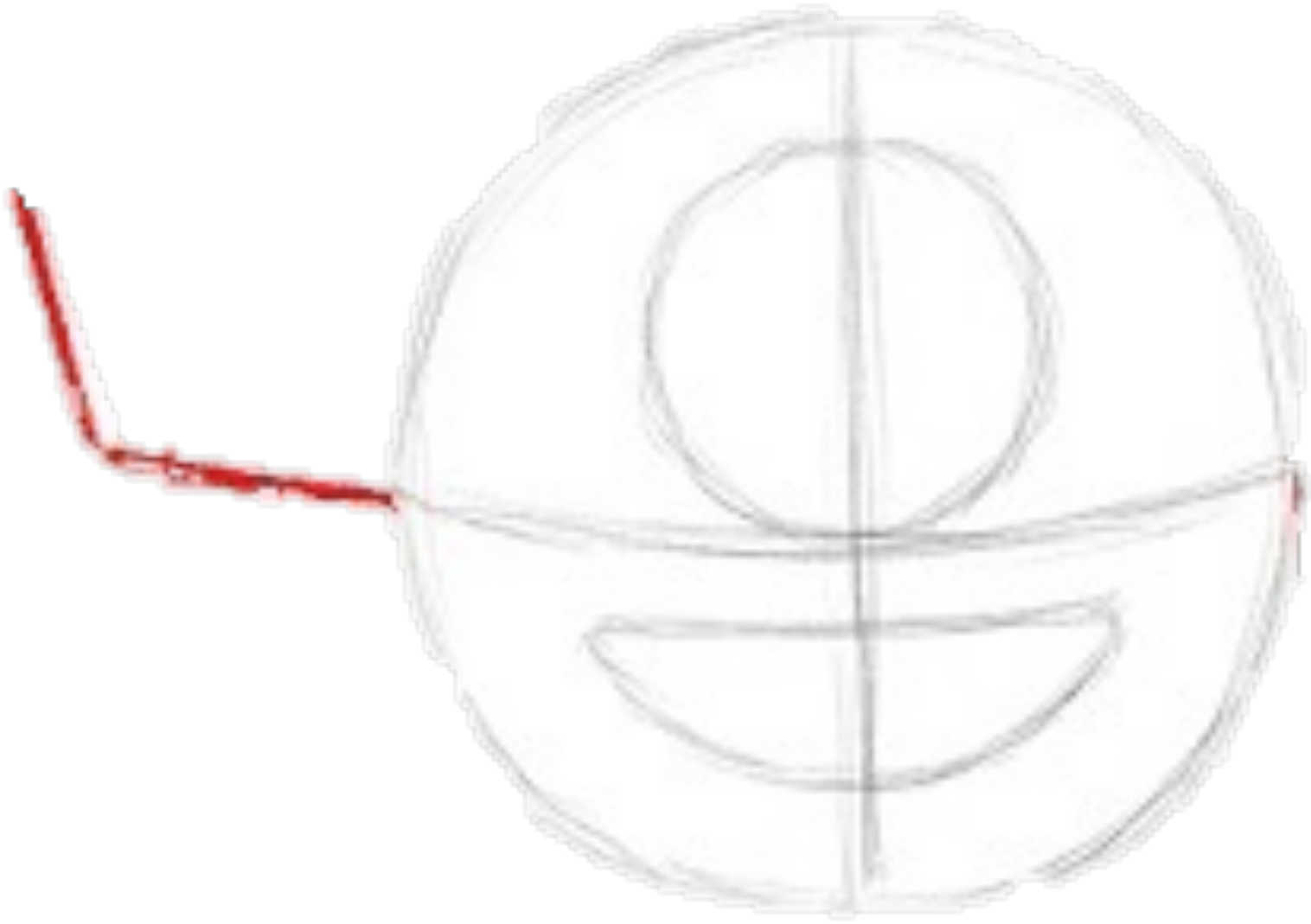
1. Draw a circle in the middle of the paper. (r ≈ 1.5in)

2. Draw a smaller circle (r ≈ 0.5in) inside the previous circle on the centered on the upper half.

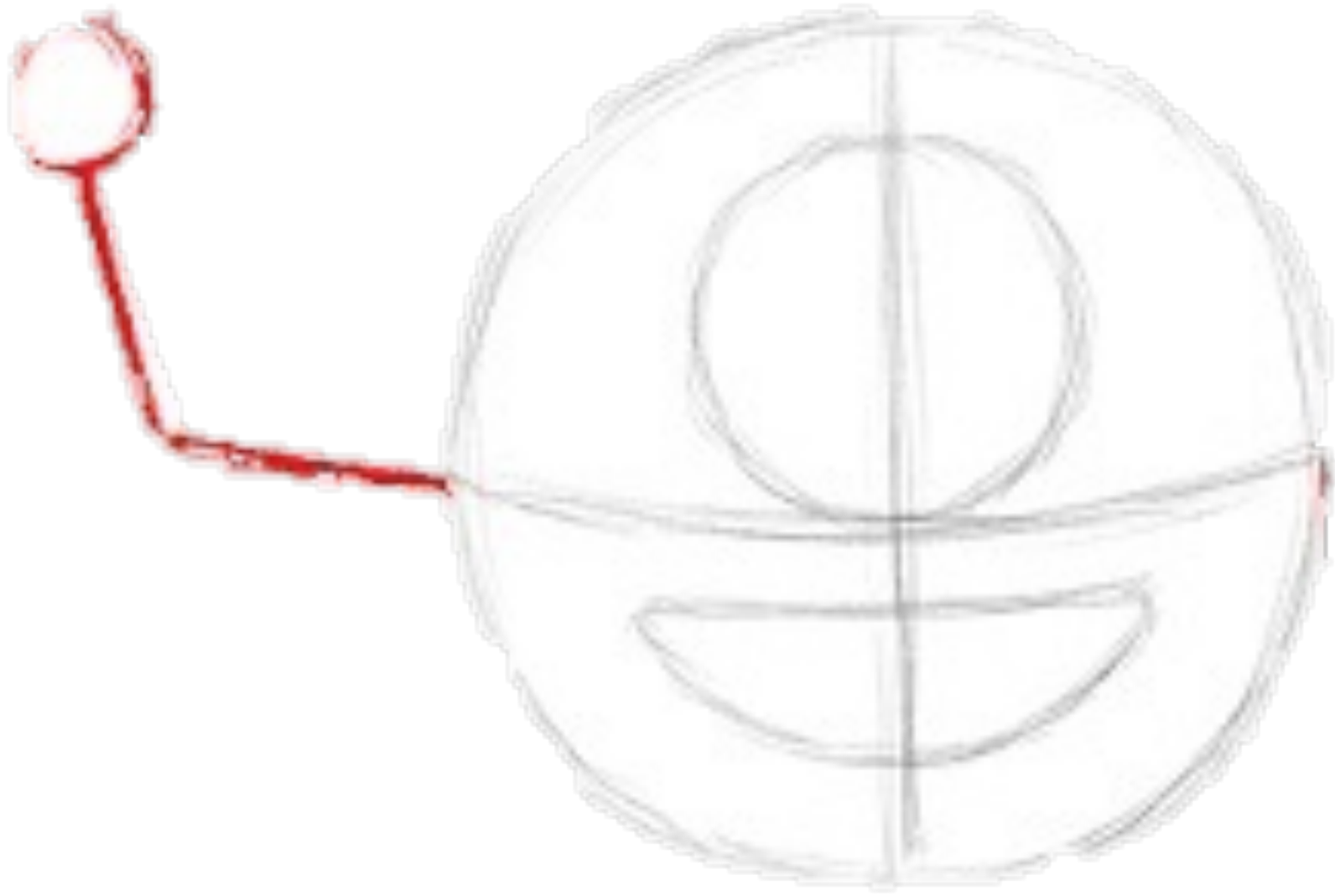
3. Inside the bottom half of the larger circle, little below the smaller circle draw a sideways D.



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.’



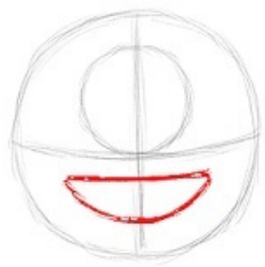
Do you see what you are drawing?

Step 1

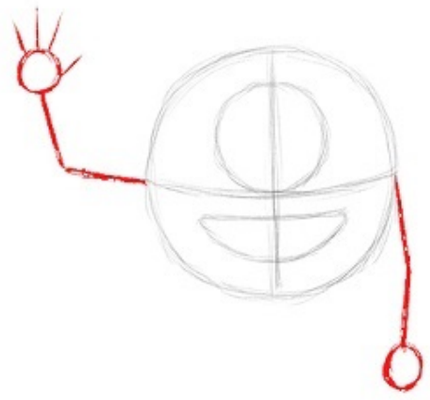
Step 2

Step 3

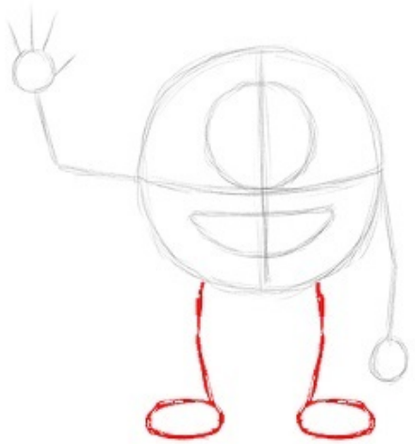
Step 4



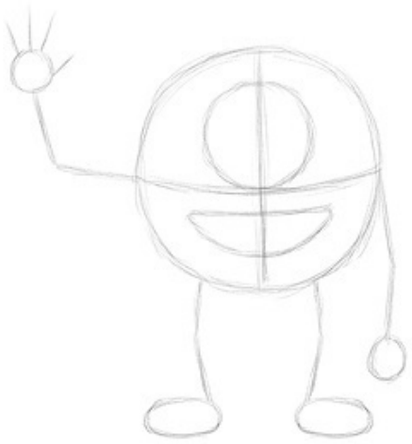
Step 5



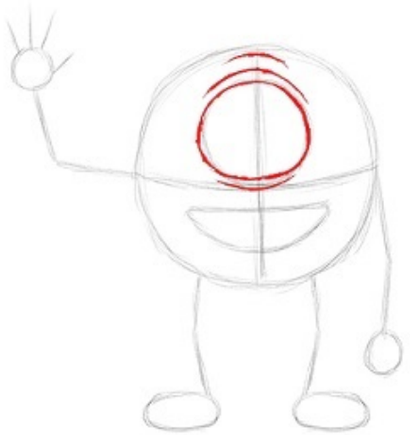
Step 6



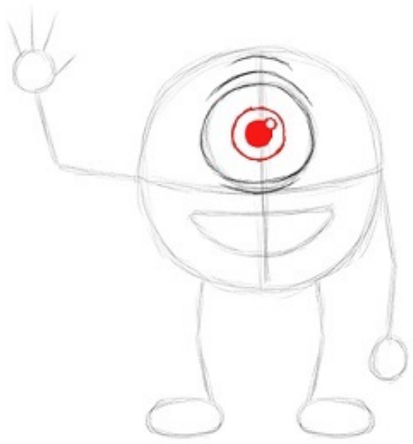
Step 7



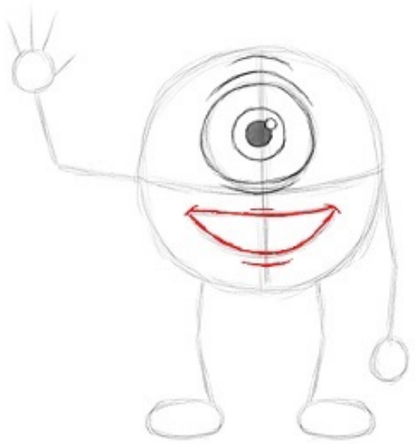
Step 8



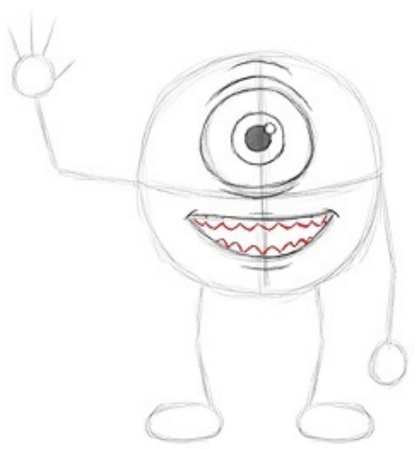
Step 9



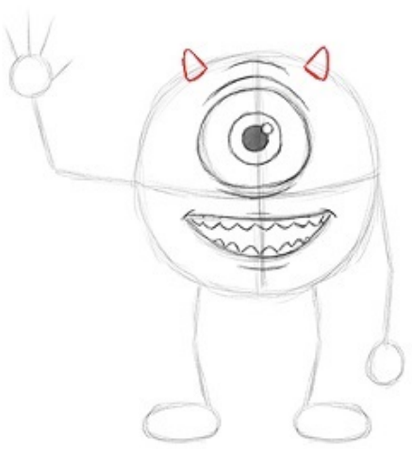
Step 10



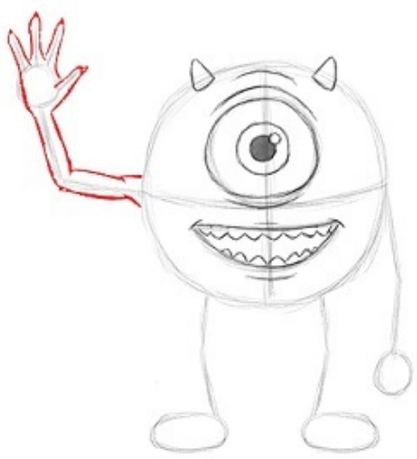
Step 11



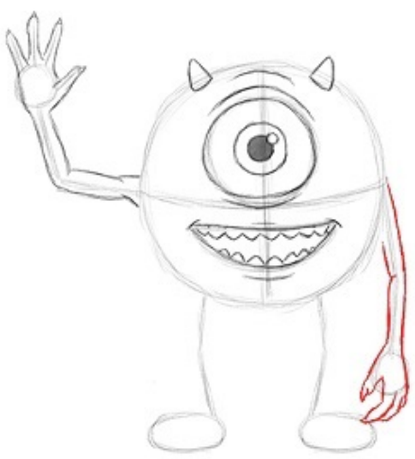
Step 12



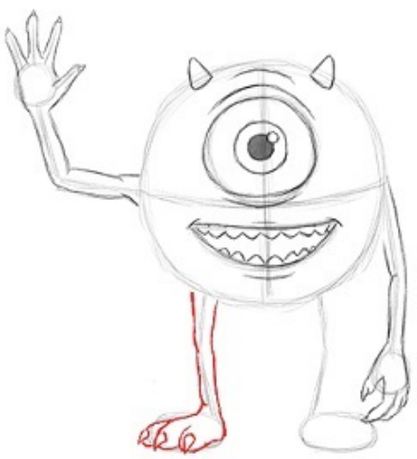
Step 13



Step 14



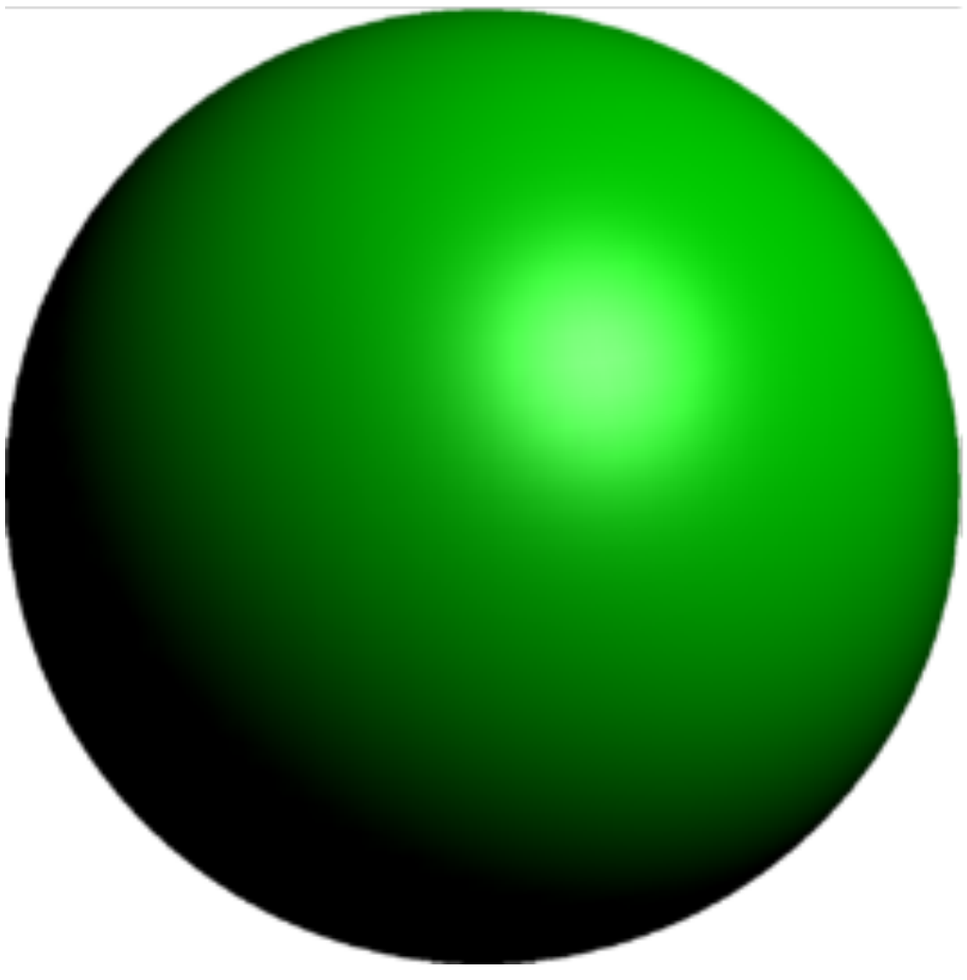
Step 15



We can represent shapes by
‘procedure.’

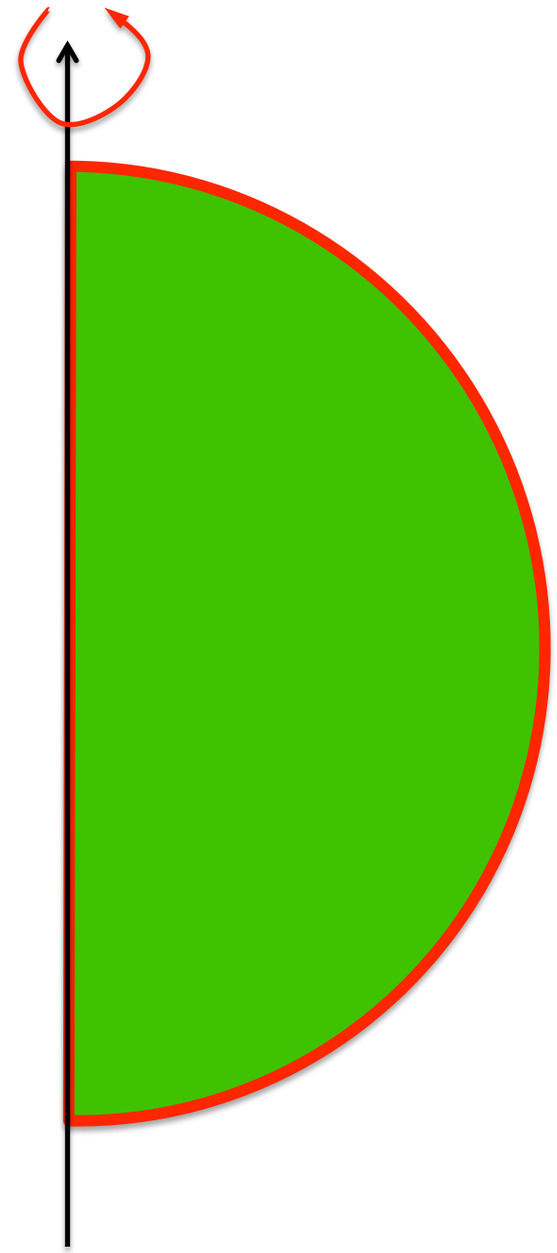
Procedural Modeling

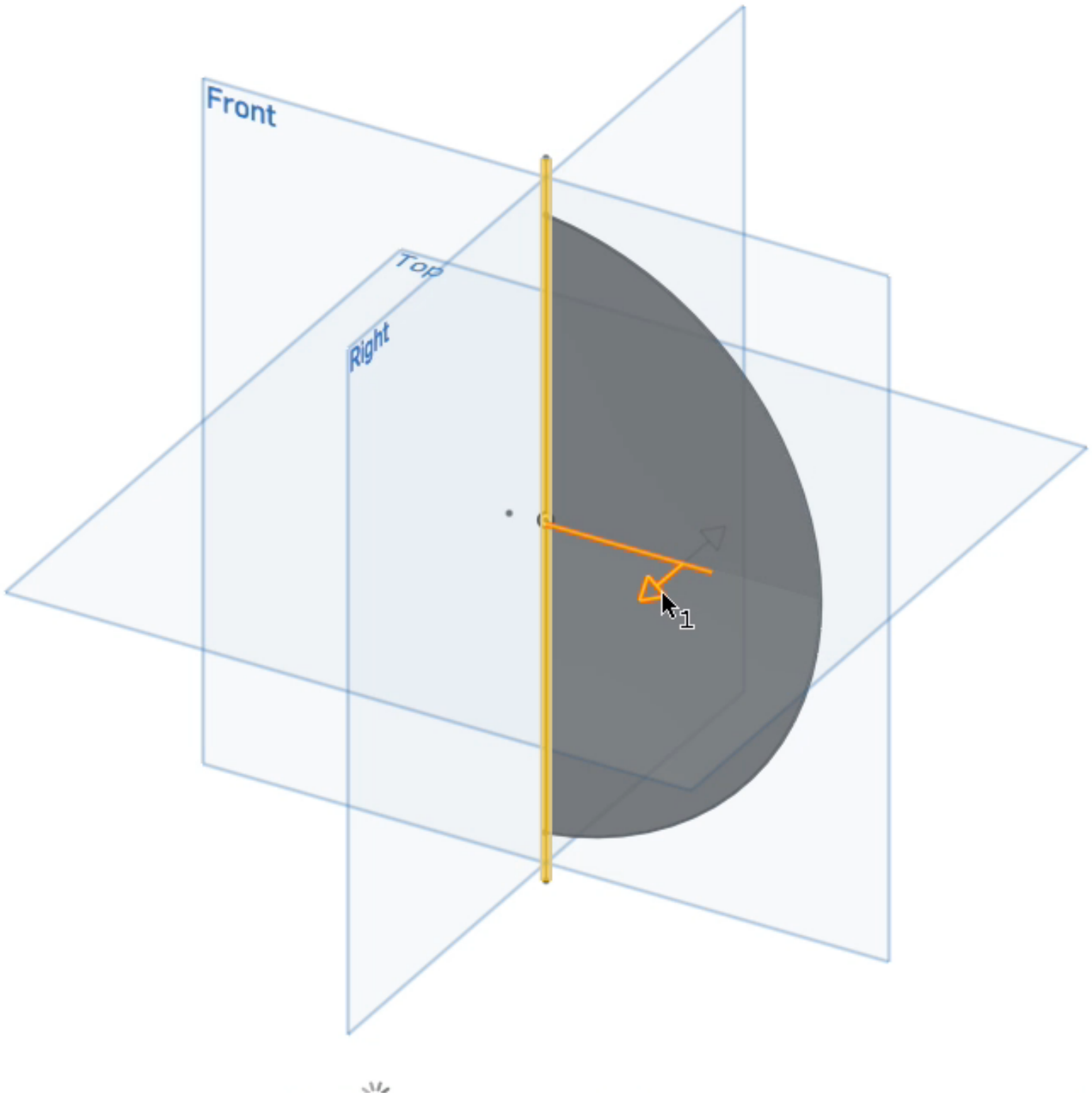
How can we *generate* a sphere?



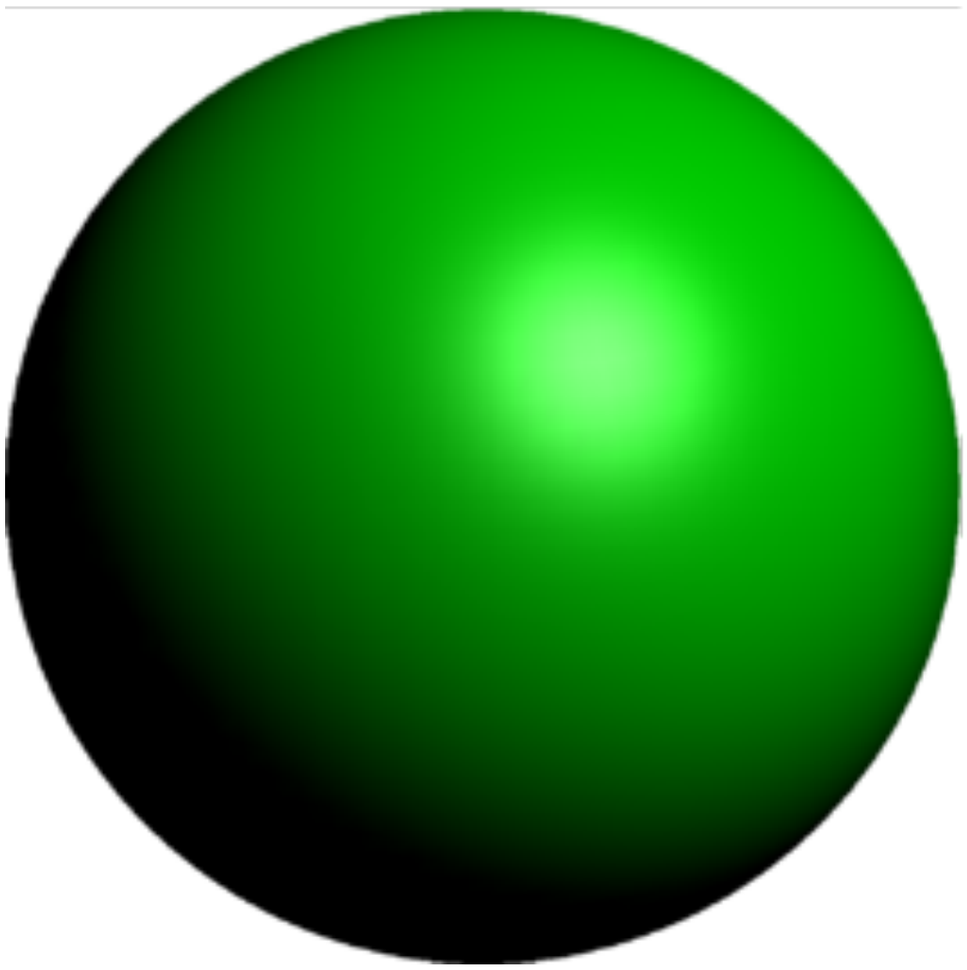
1.Take a half moon

2.Revolve it around the center

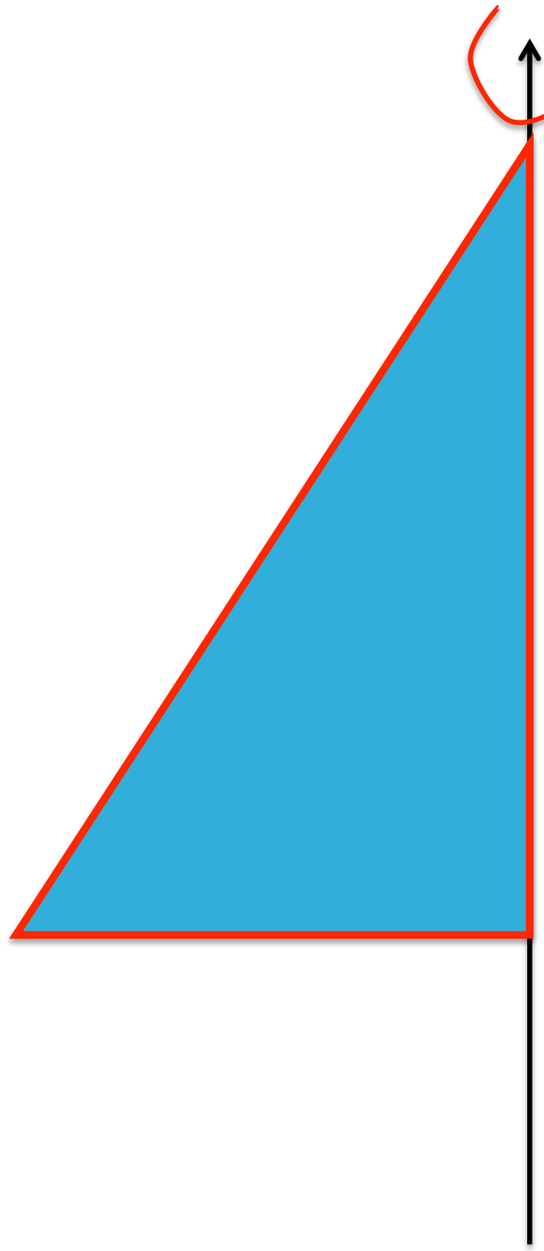


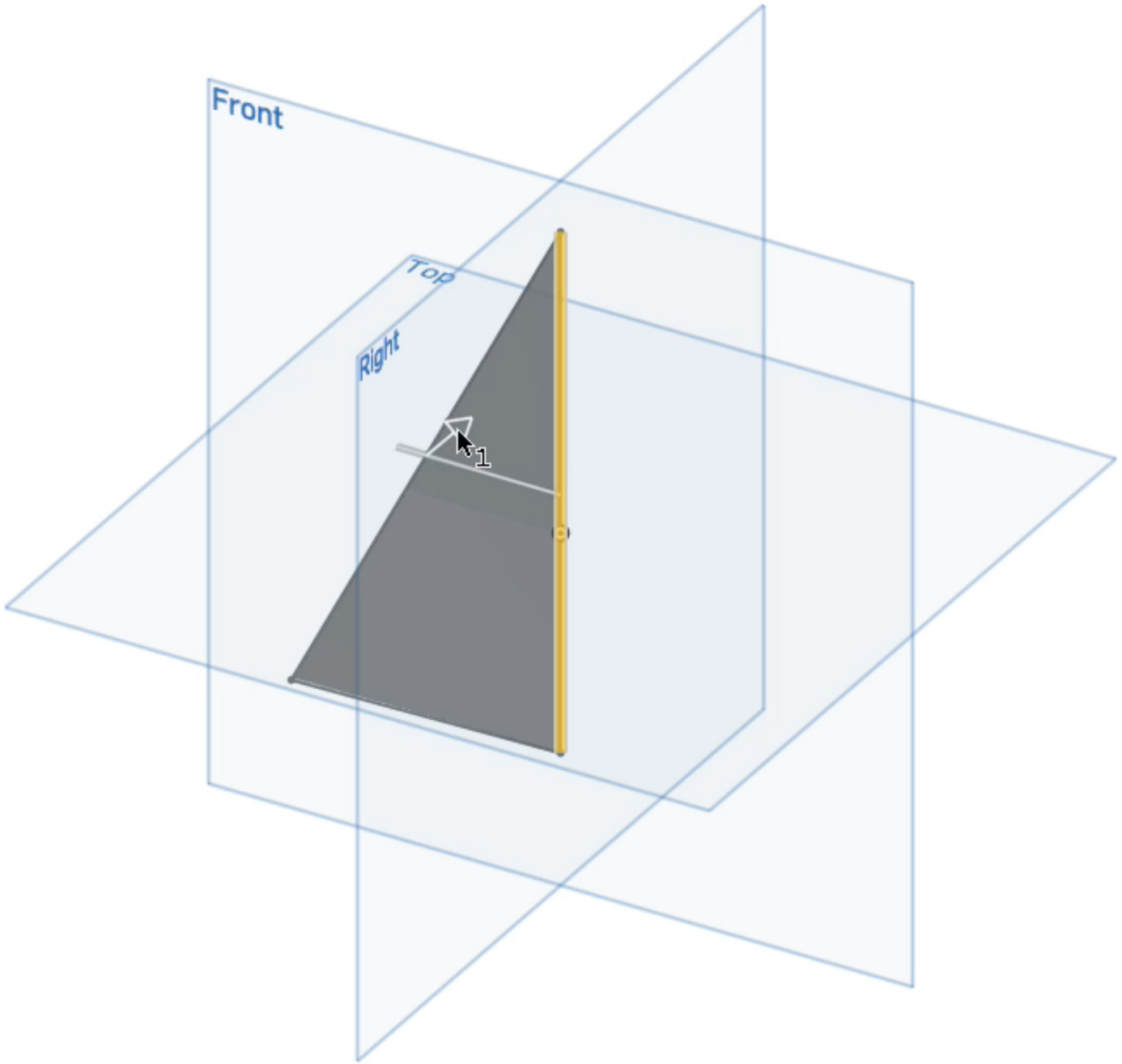

Front
Top
Right
1

How can we *generate* a sphere?



Change shape :: triangle

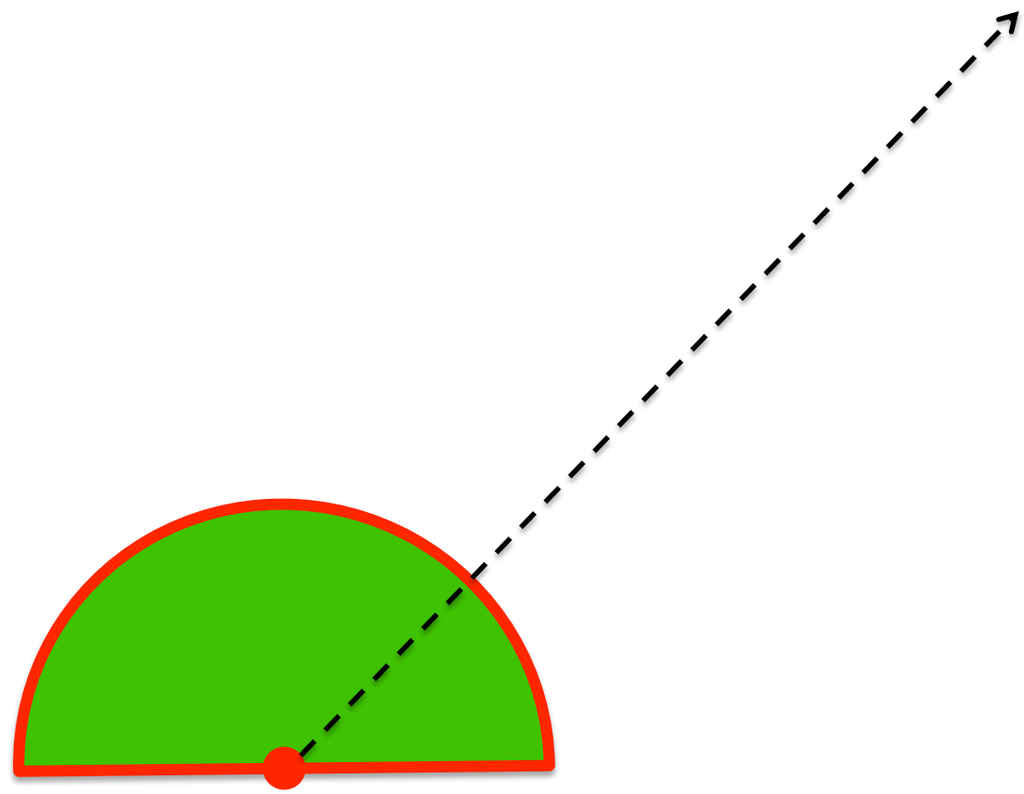


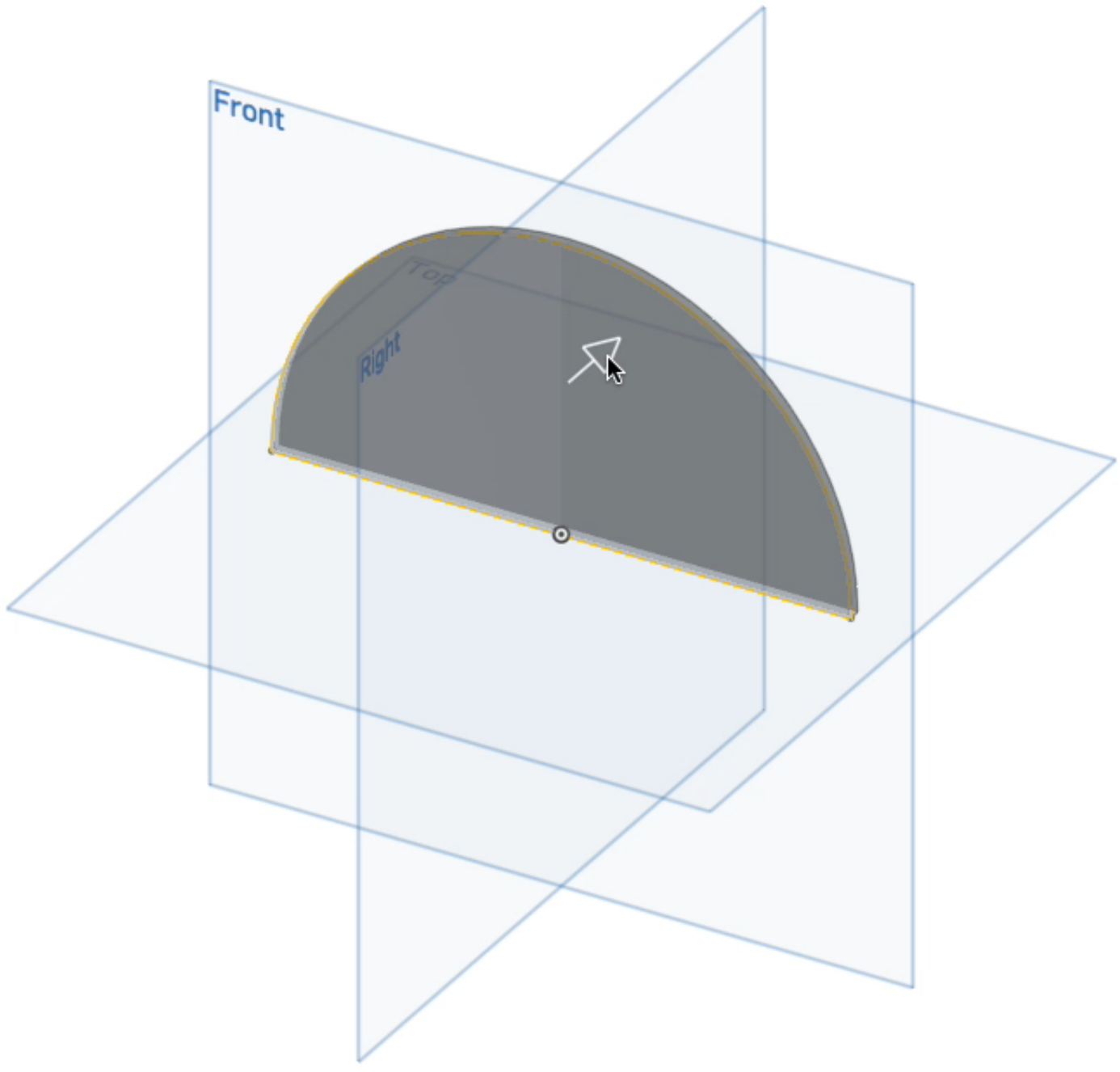

Front
Top
Right
1

Change shape :: triangle

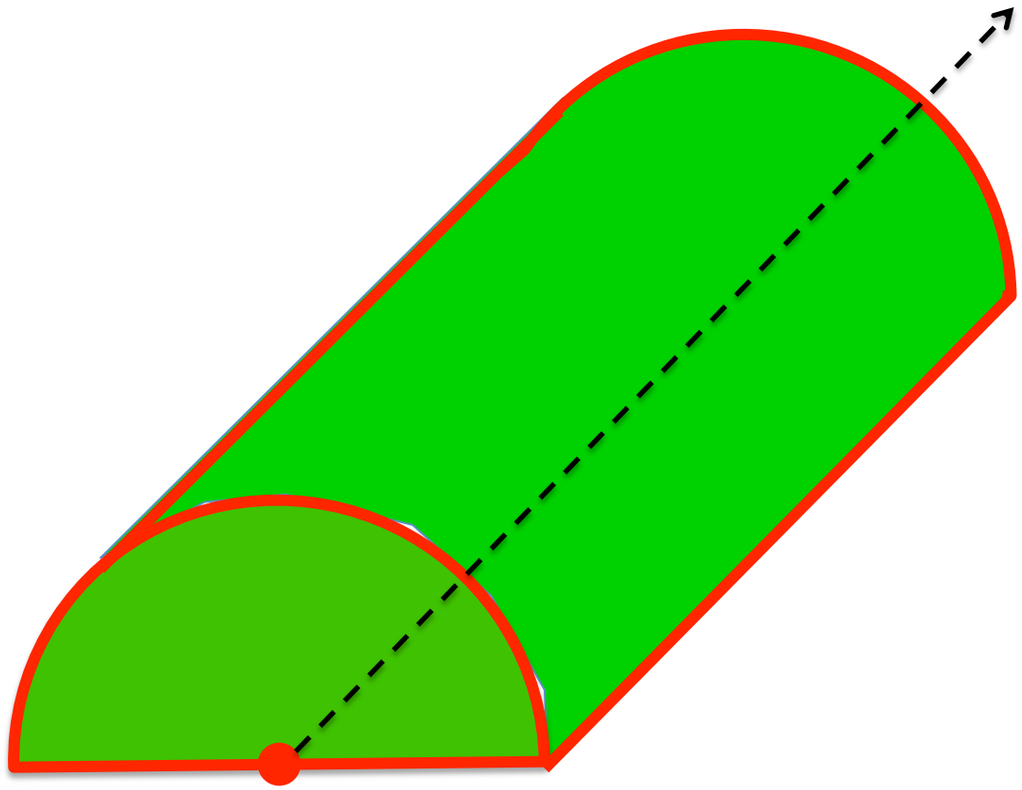
and many more…

Change motion:: extrude

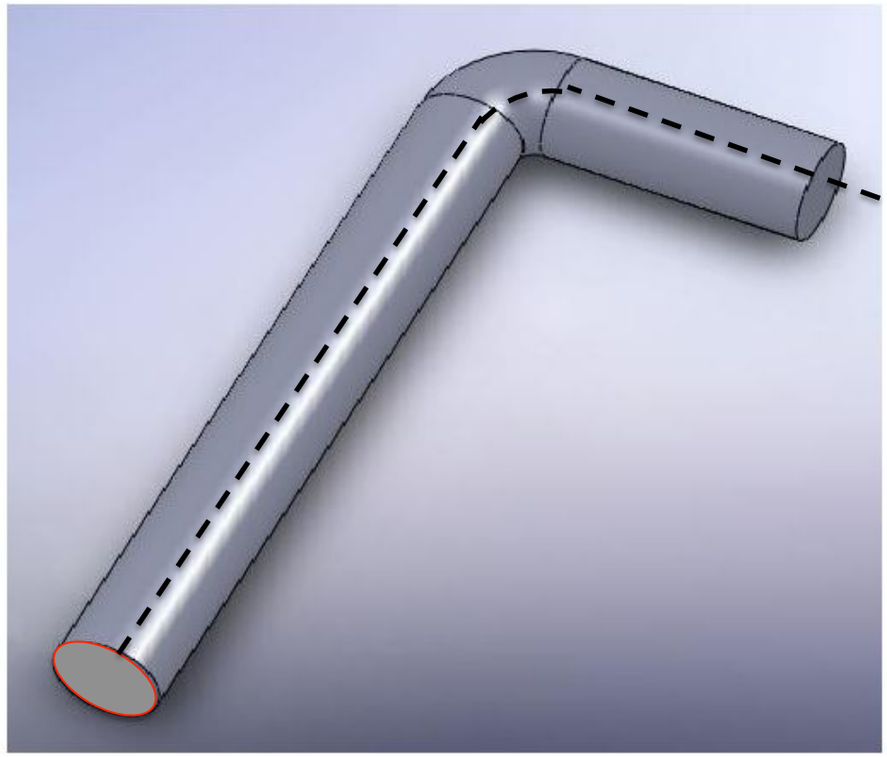


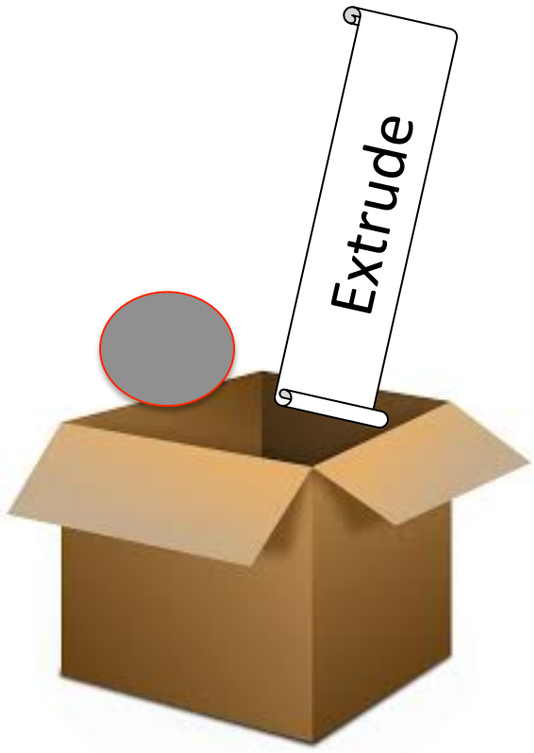

Front
Top
Right

Change motion:: extrude

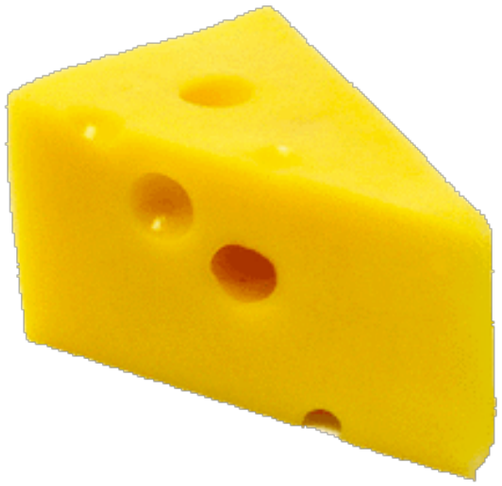


Change motion:: curve



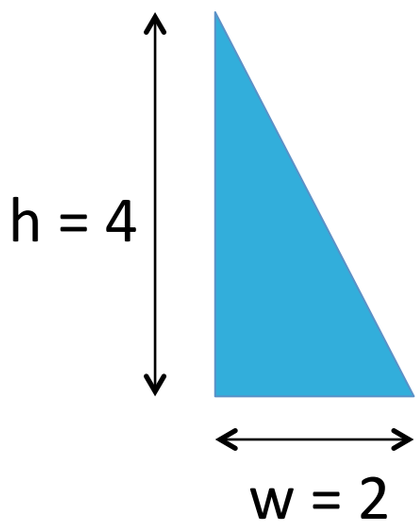


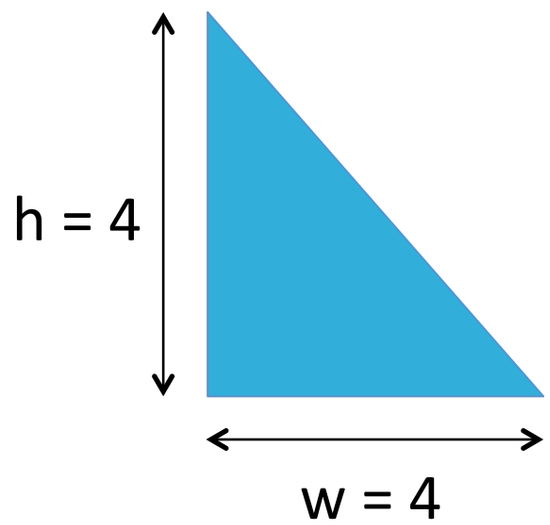
And many more…

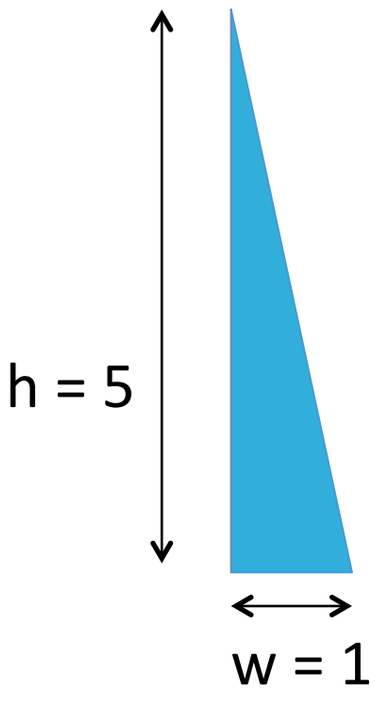


Add parameters

Shapes have parameters.

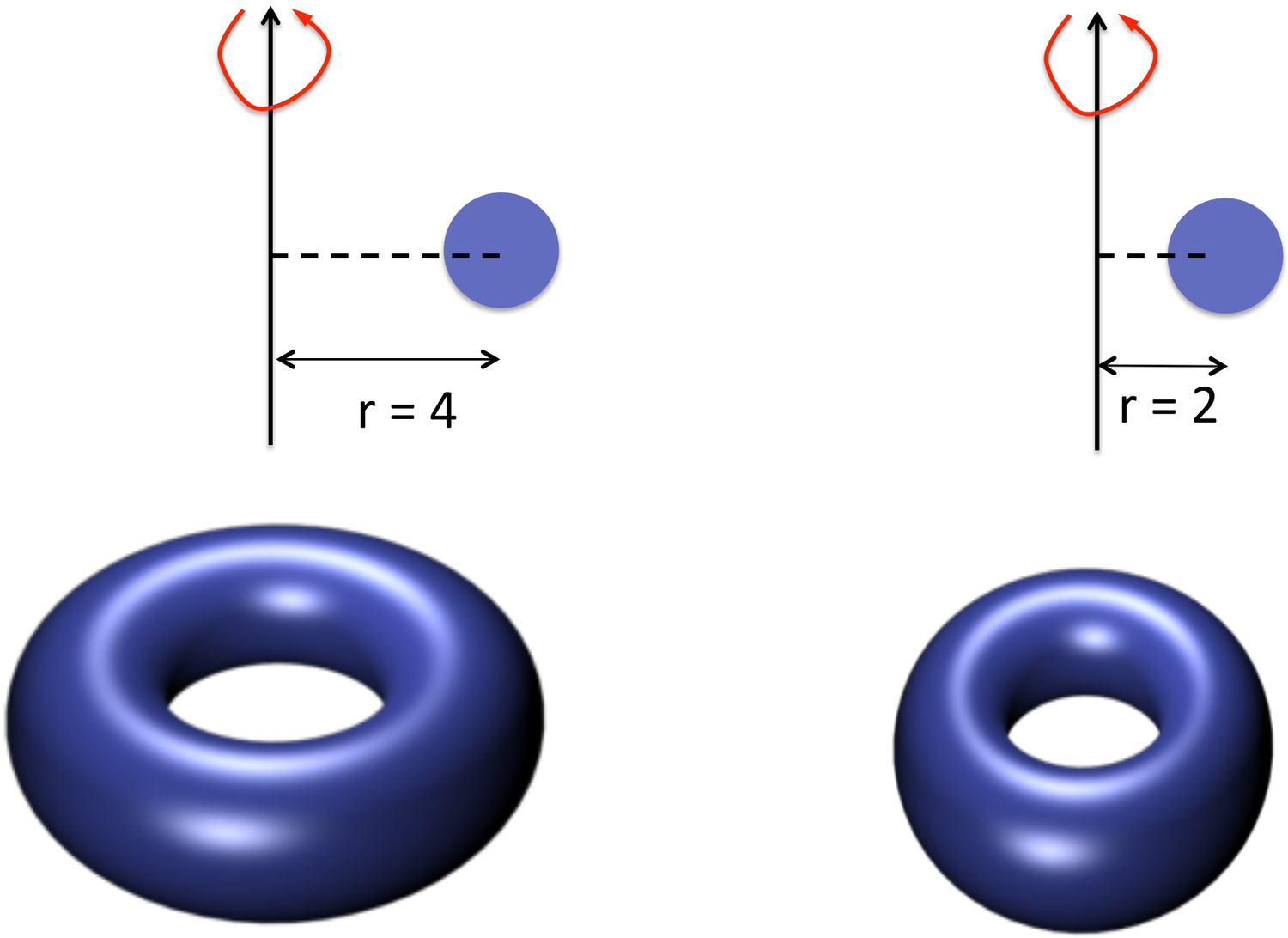






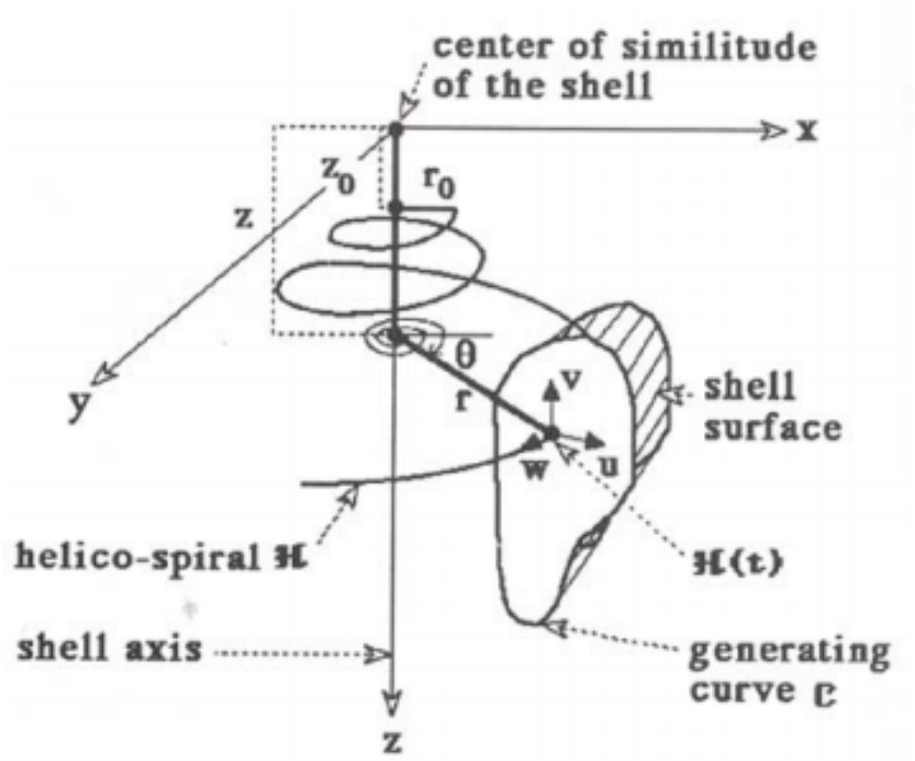
Add parameters

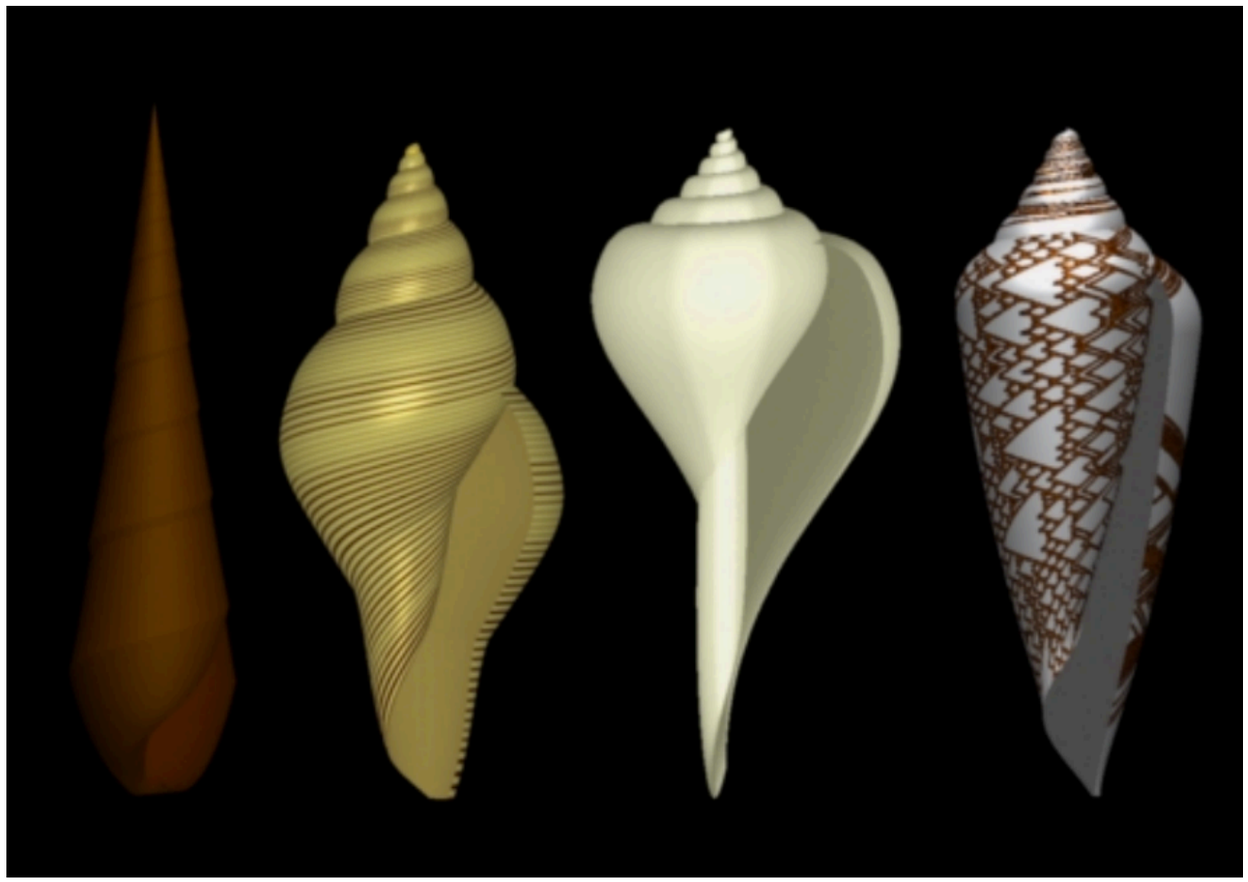
Paths have parameters.



Add parameters

Generate different shapes by varying parameters

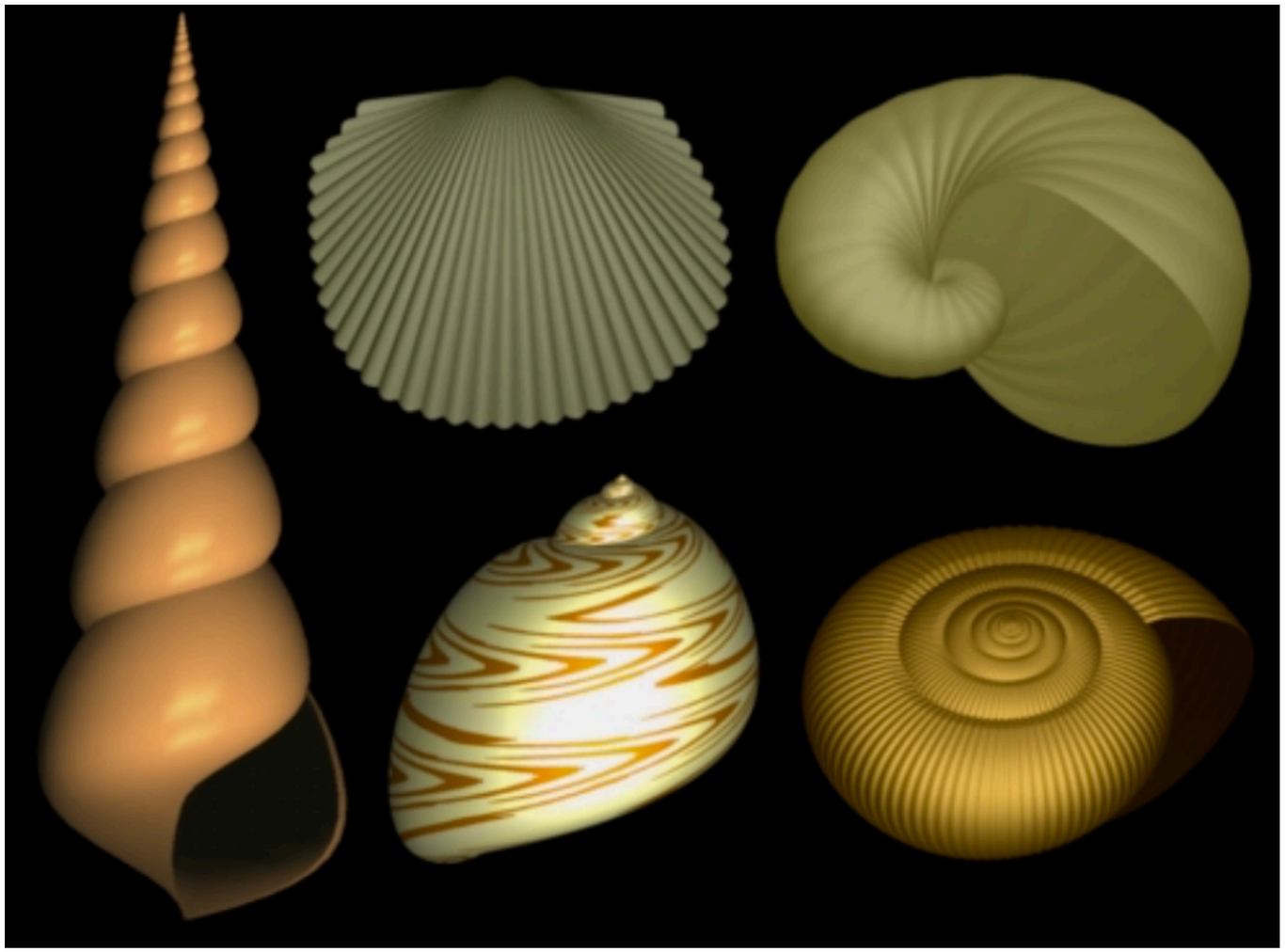




Modeling Seashells / Fowler et al., SIGGRAPH 1992

Add randomness

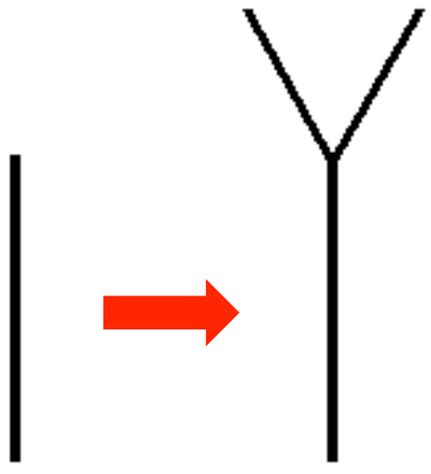
Add randomness to parameters or procedures to generate crowds of objects

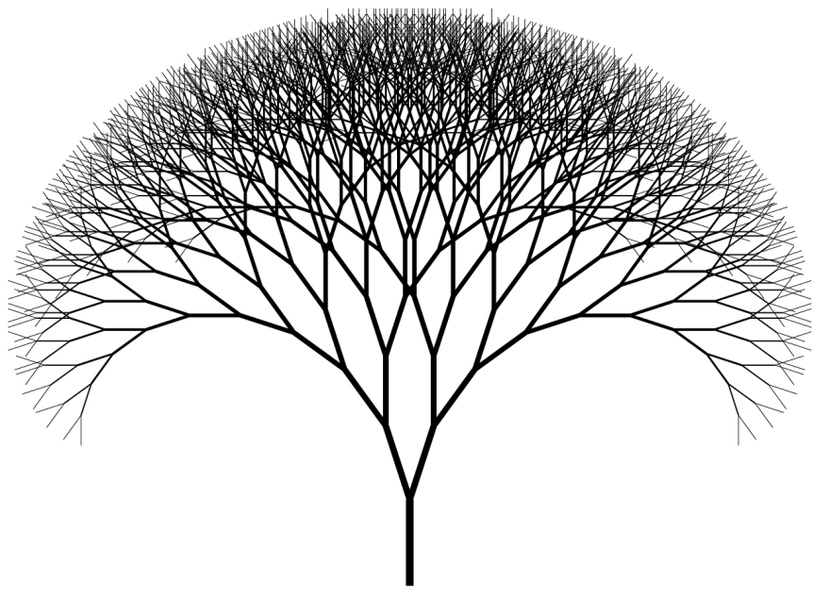


Modeling Seashells / Fowler et al., SIGGRAPH 1992

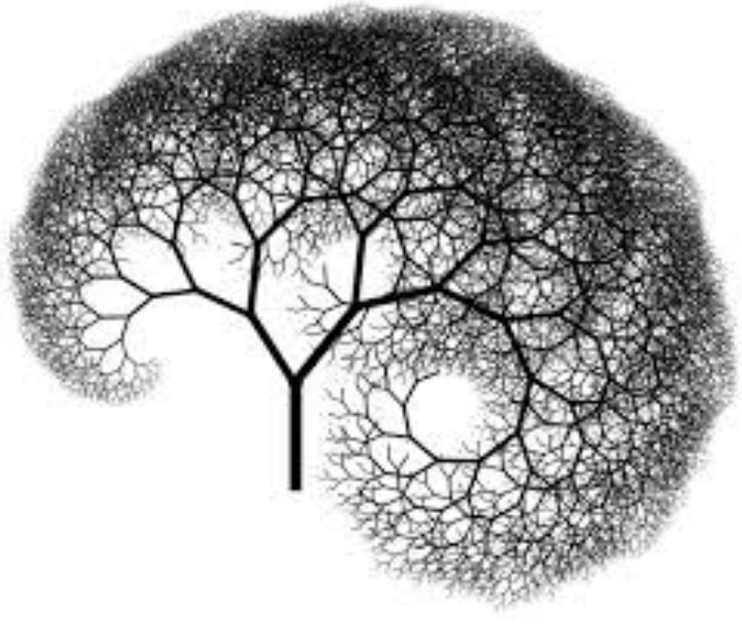
There are *many different* procedures!

- e.g. split branch





http://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

Procedural Modeling of Buildings / Muller et al, SIGGRAPH 2006

Brave (2012)

Wall-E (2008)

Cars 2 (2011)

Presented by Zoya Bylinskii

PUTTING IT ALL TOGETHER

Choosing a representation

Design decisions:

- What are your **primitives**?
- What **operations** do you perform on them?

Factors to consider:

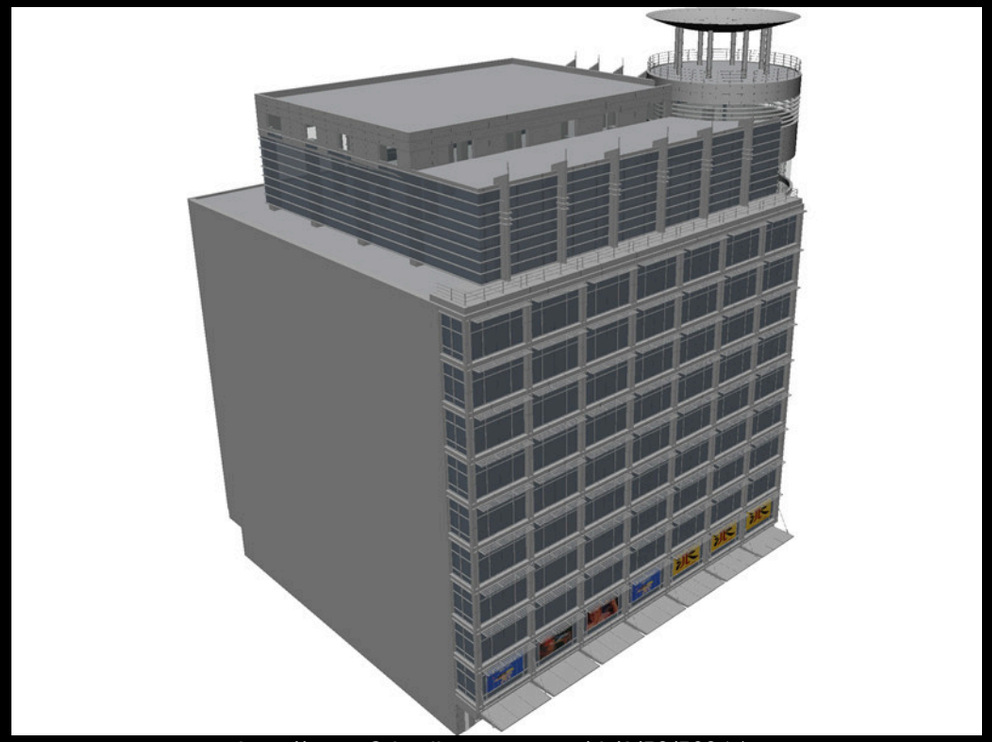
- How detailed or **accurate** is the representation?
- How much storage space is required? Is the representation **efficient**?
- What is the use case or **usability** of the representation? What should you be able to do with it?

Now let's apply your knowledge

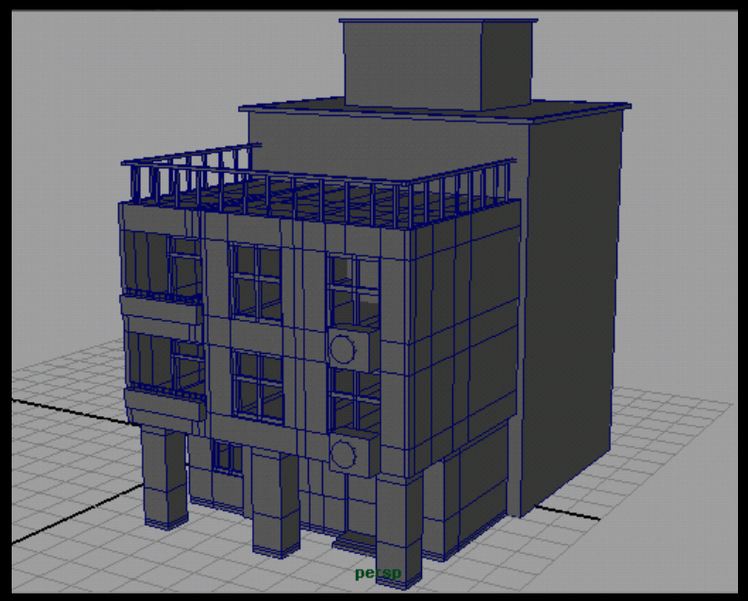
How to model a building?

How to model a building?

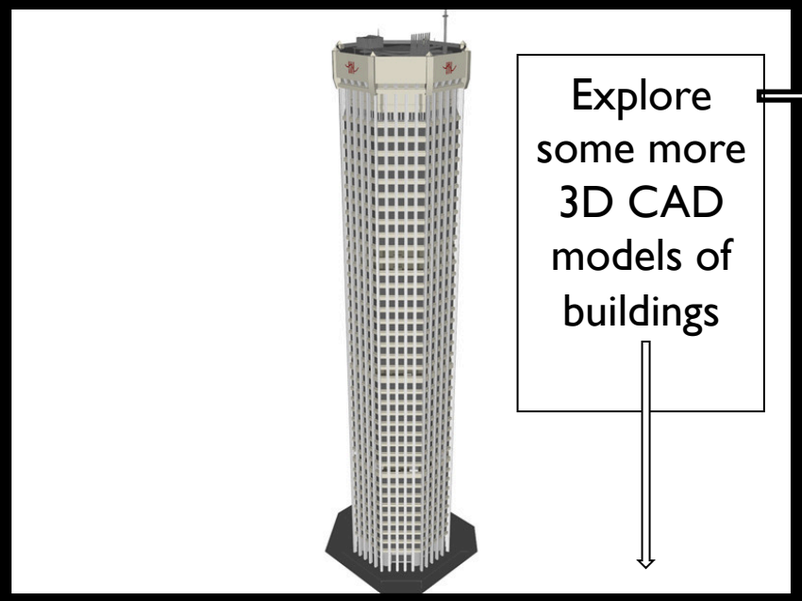
http://www.vfxer.com/free-buildingskyscraper-element-3d-model-pack/



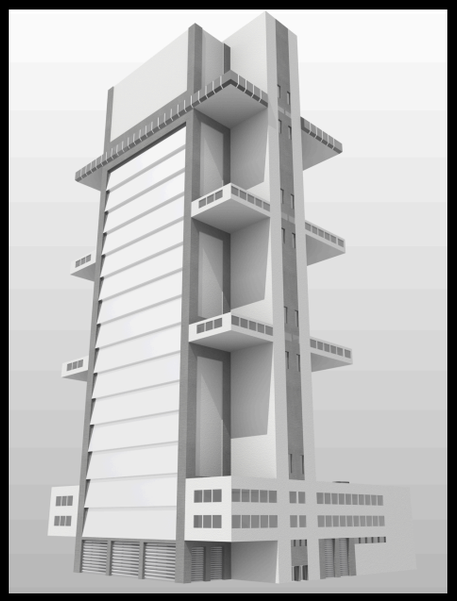
http://www.3dcadbrowser.com/th/1/59/59264.jpg



https://franklyfrankie.files.wordpress.com/2011/02/building-2-model-wip.jpg

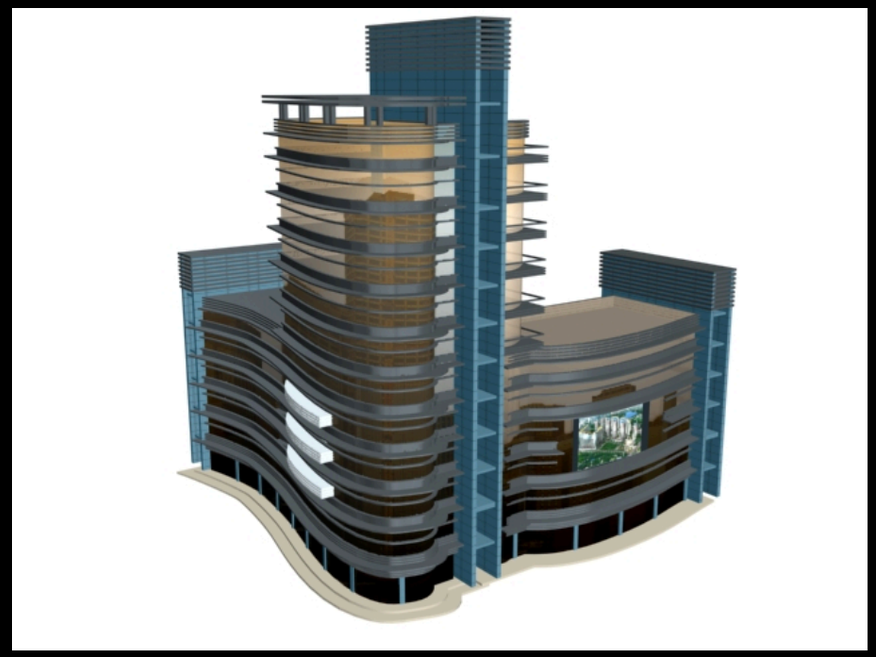


http://www.3dcadbrowser.com/download.aspx?3dmodel=6960



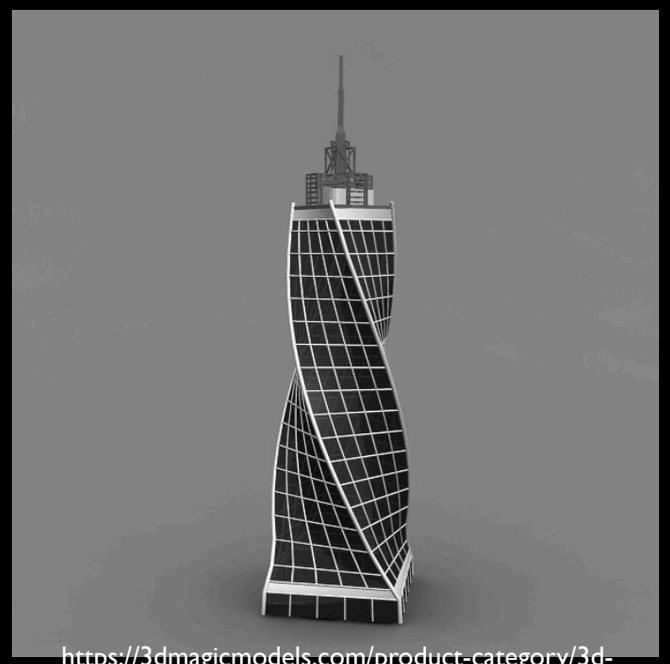
http://yehuna.deviantart.com/art/Stardust-Tech-Building-Model-251687788

With added complexity



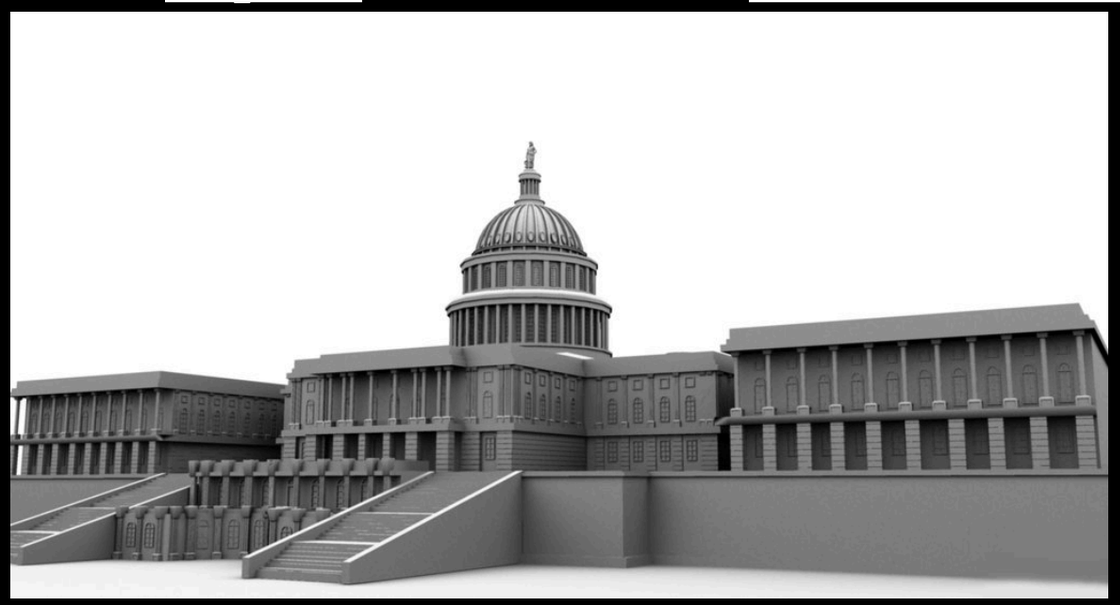
http://imgbuddy.com/simple-3d-building-models.asp

http://open3dmodel.com/download/building-3-3d-model_6370.html



https://3dmagicmodels.com/product-category/3d-models/architecture/structures/store/

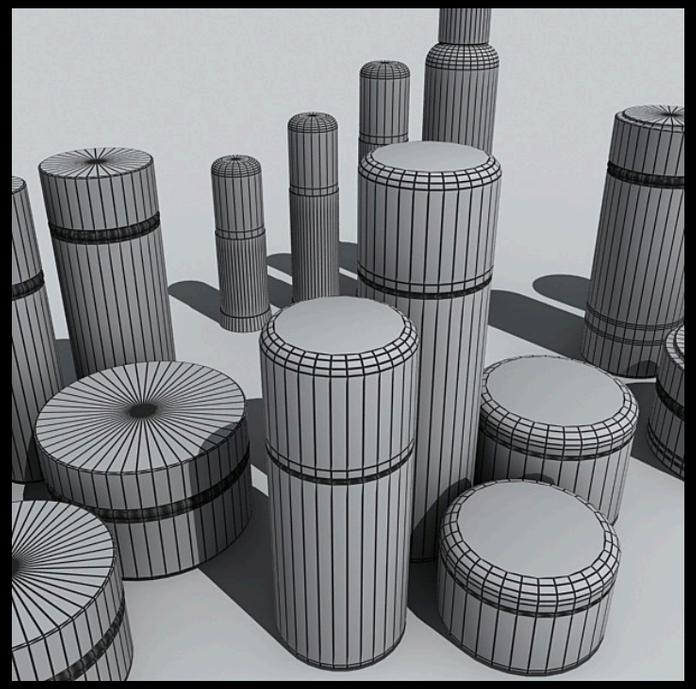
http://4-designer.com/2013/01/Ancient-Temples-3D-models-of-ancient-temples/#.VI3s-mSrQUE



http://fr3dosart.deviantart.com/art/Senate-Building-3D-model-for-a-client-395203327

How to model a city?

How to model a city?



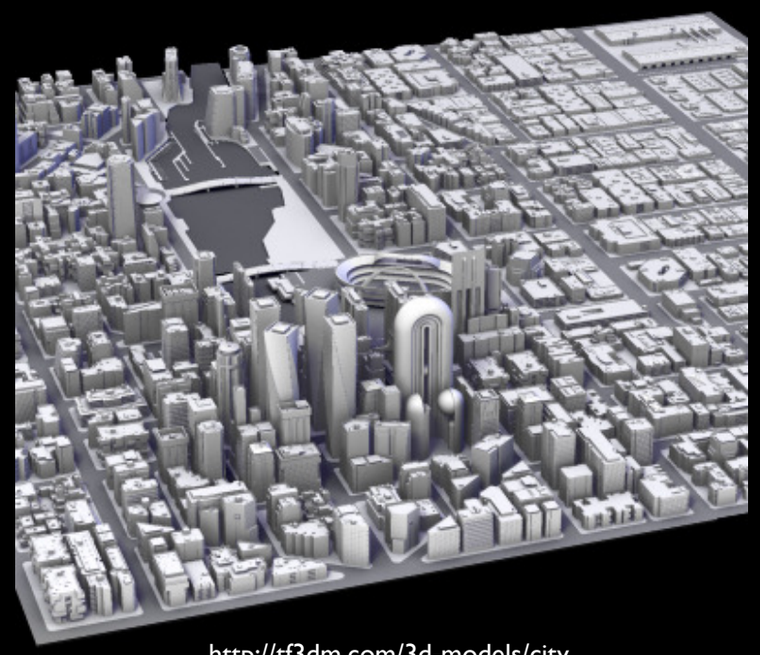
http://www.turbosquid.com/3d-models/cosmetic-set-3-3d-model/420486

http://www.turbosquid.com/3d-model/building/

Create your own paper models of buildings

http://paperhighrise.weebly.com/

http://vastureview.com/wp-content/uploads/2015/03/large_detailed_high_rise_building_complex_3d_model_3d_model_max__6140d29e-c2ee-408a-99d9-f26f65fee470.jpg



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

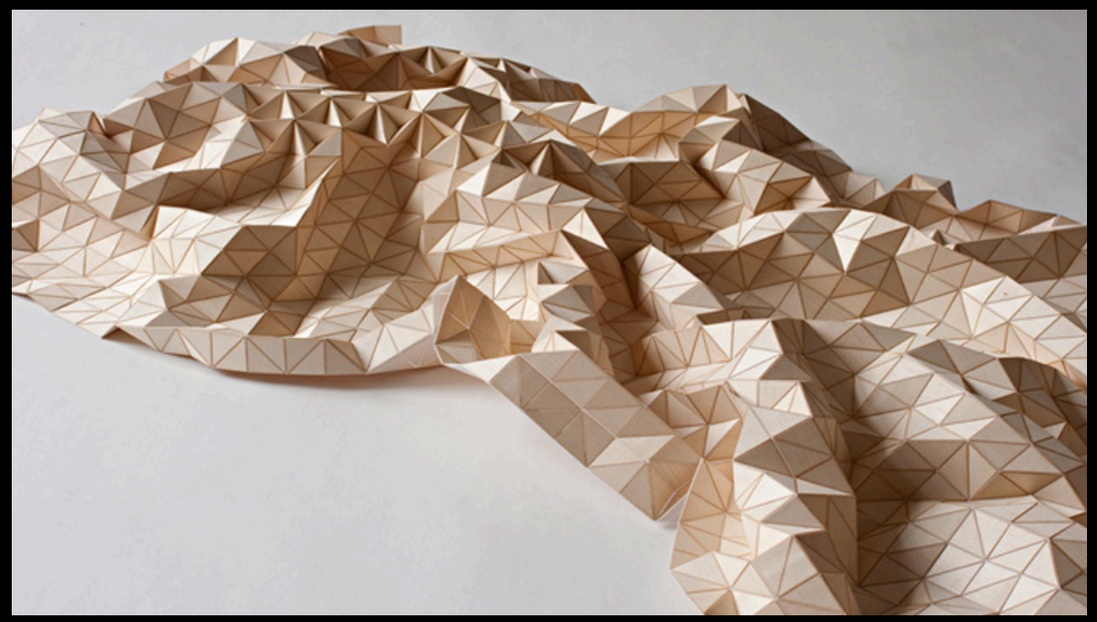
How to model a city?

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

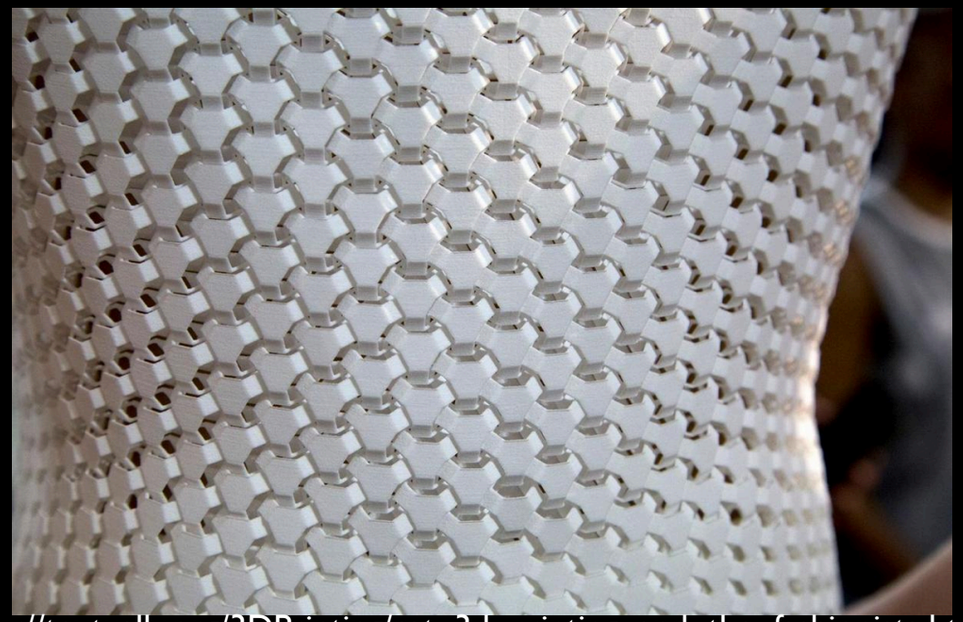
https://upload.wikimedia.org/wikipedia/commons/8/8d/HK_PolyU_Hung_Hom_Bay_Campus_8_Hung_Lok_Road_HKCC_building_model_location_Mar-2013.JPG

How to model fabric?

How to model fabric?



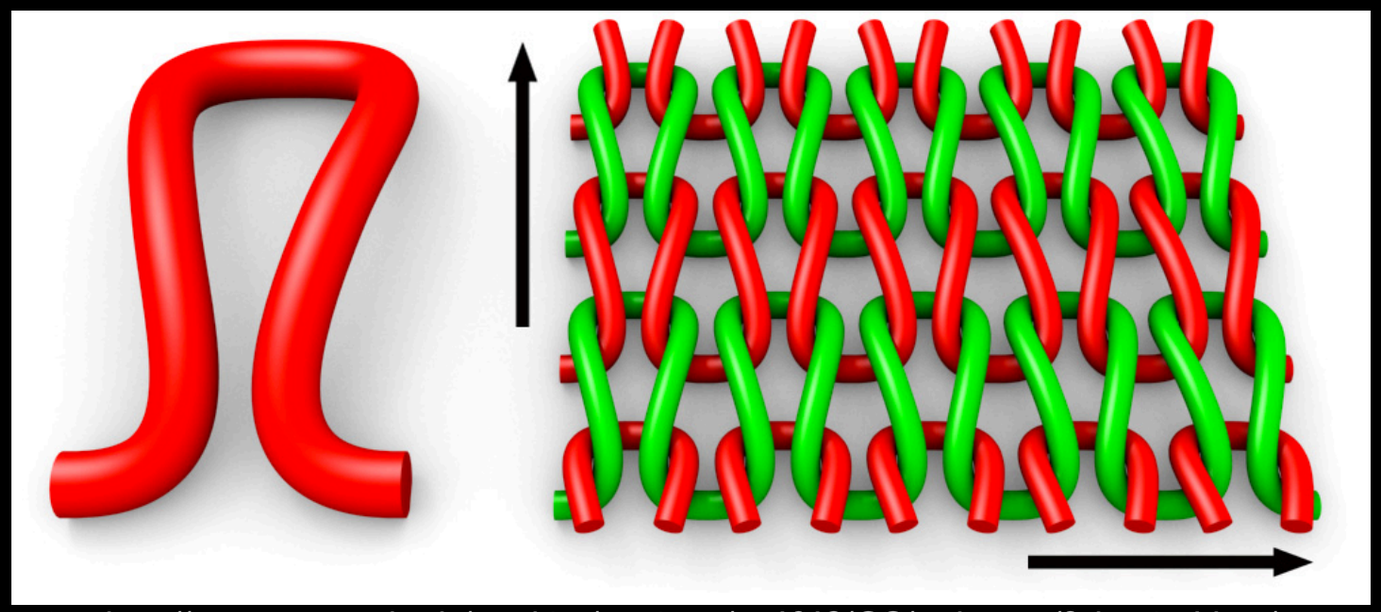
http://www.elisastrozyk.de/



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

See more examples of 3D printed fabrics and clothes

Learn about how knitted clothing can be computationally simulated

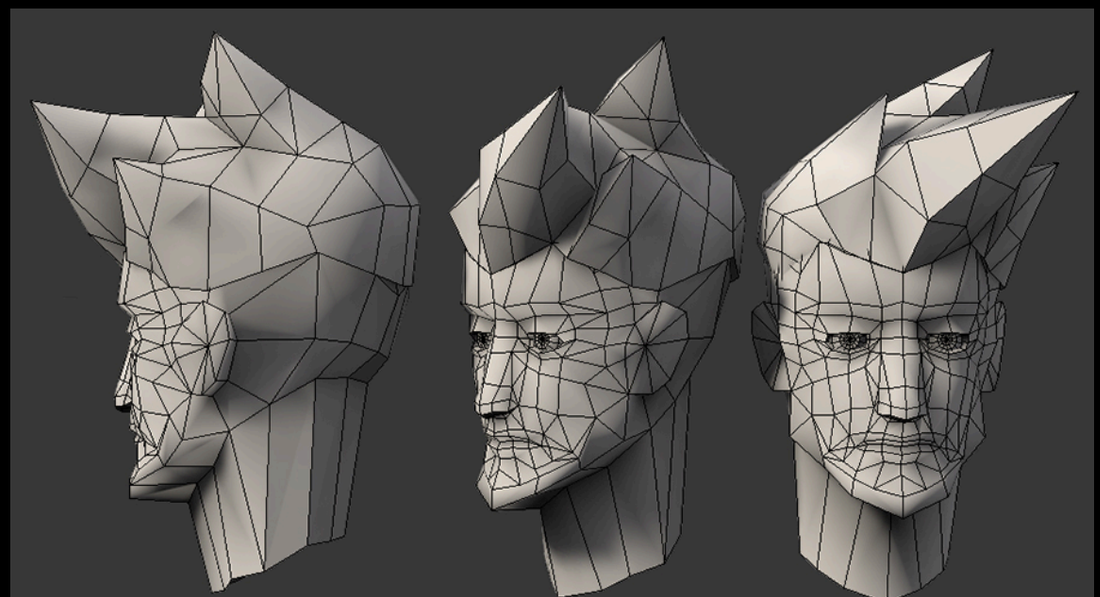


http://www.cg.cs.tu-bs.de/teaching/seminars/ws1213/CG/webpages/SebastianMorr/

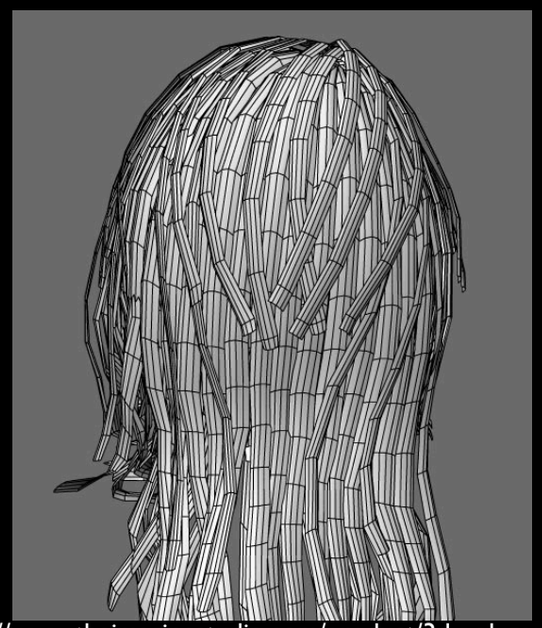
How to model hair?

How to model hair?

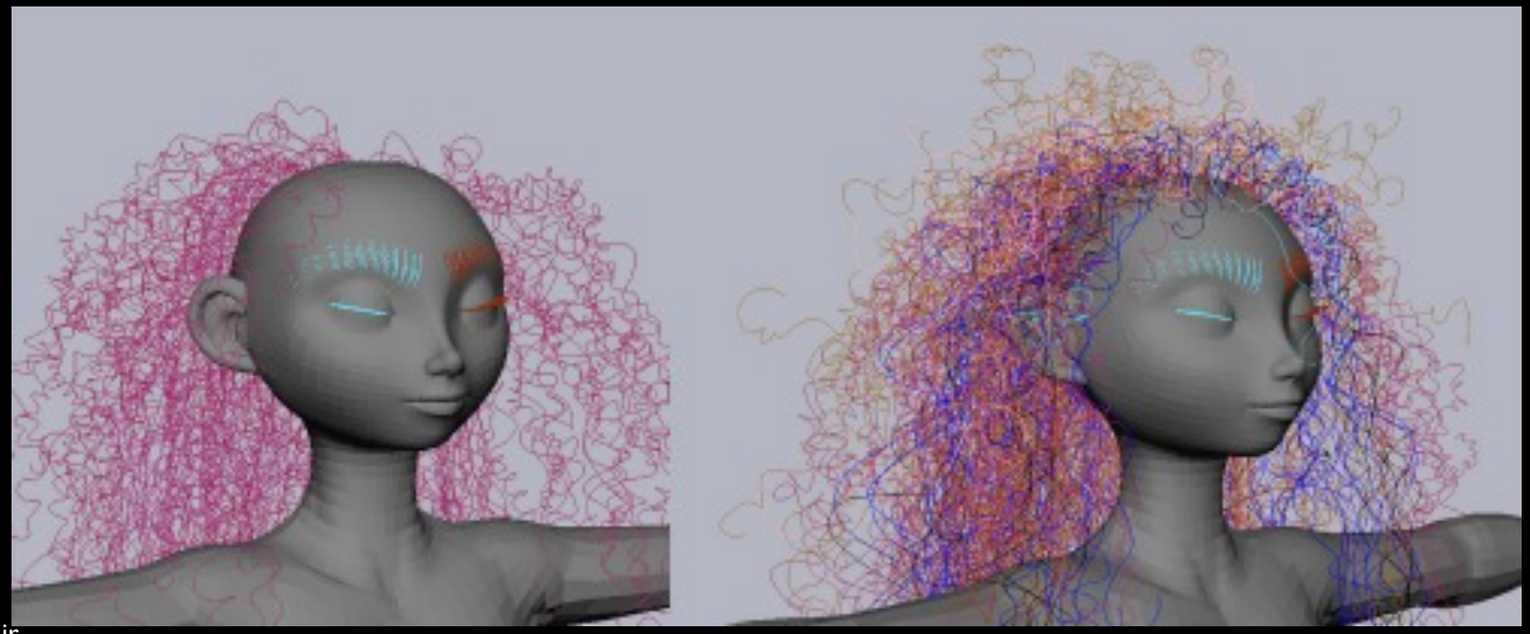
http://www.sharecg.com/v/57153/related/5/3d-model/blue-hair-genesis



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



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

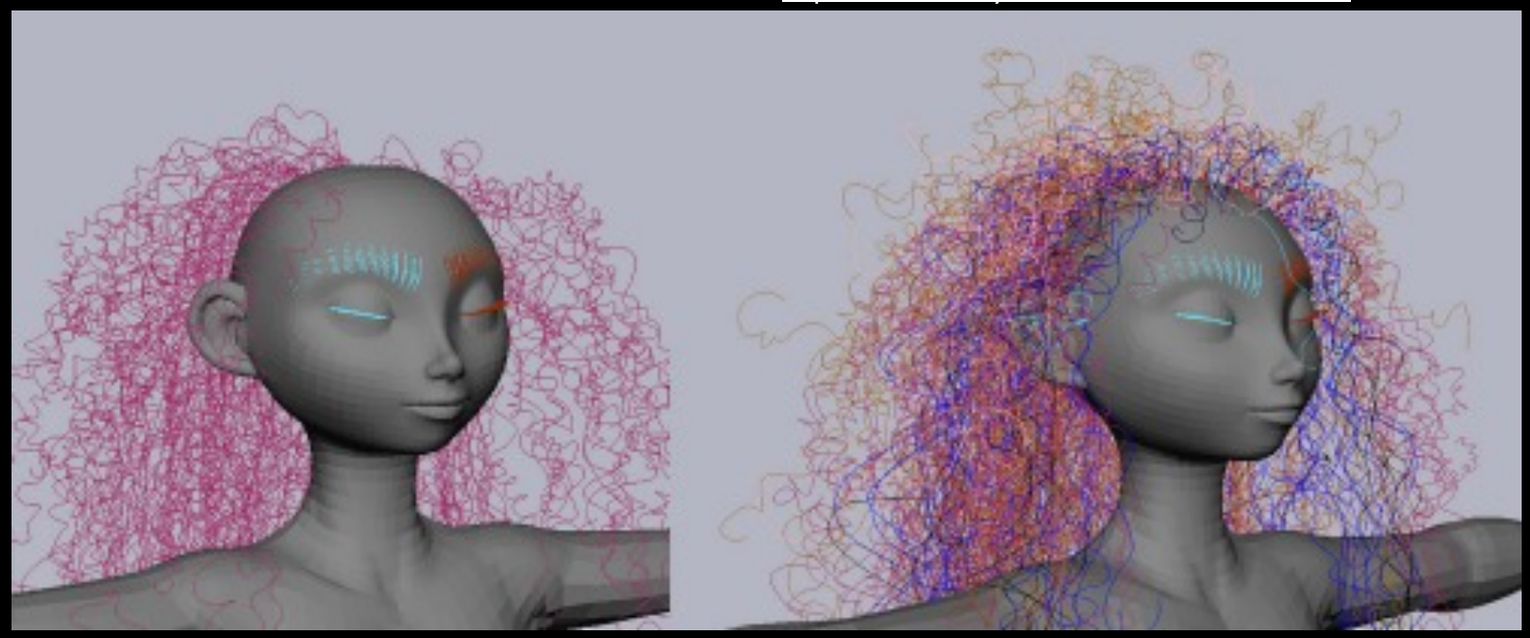


https://www.fxguide.com/featured/brave-new-hair/

Read more about behind the scenes of Pixar's Brave

How to model hair?

http://www.themarysue.com/new-brave-featurette/



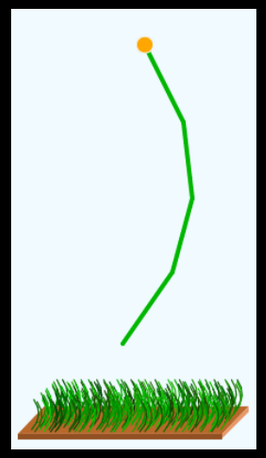
https://www.fxguide.com/featured/brave-new-hair/

Video demo about Merinda's hair: https://www.youtube.com/watch?v=Cecx5HVtUDY

How to model grass?

How to model grass?

Parabola

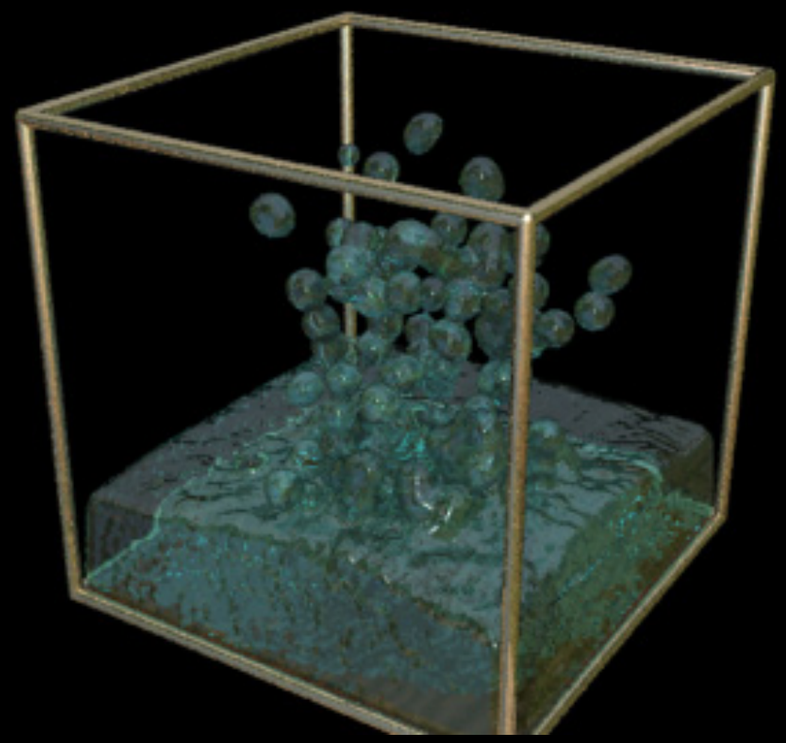


Pixar in a box
(Khan Academy)

https://www.khanacademy.org/partner-content/pixar/environment-modeling-2/animating-parabolas-ver2/a/start-here-em

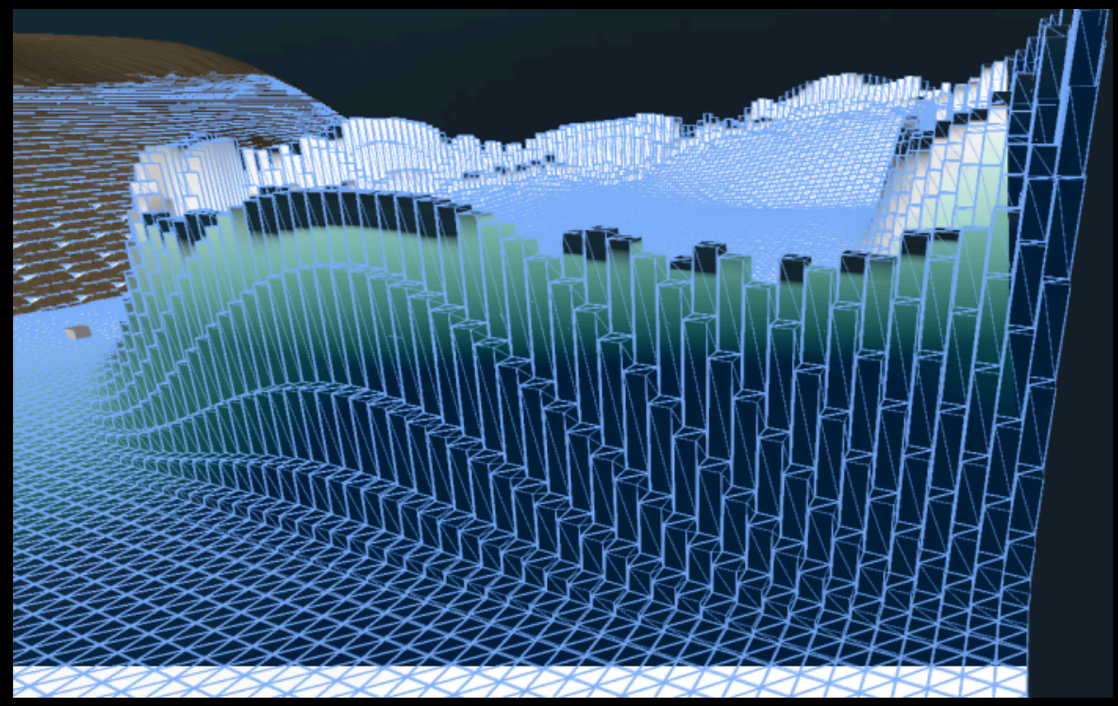
How to model water?

How to model water?

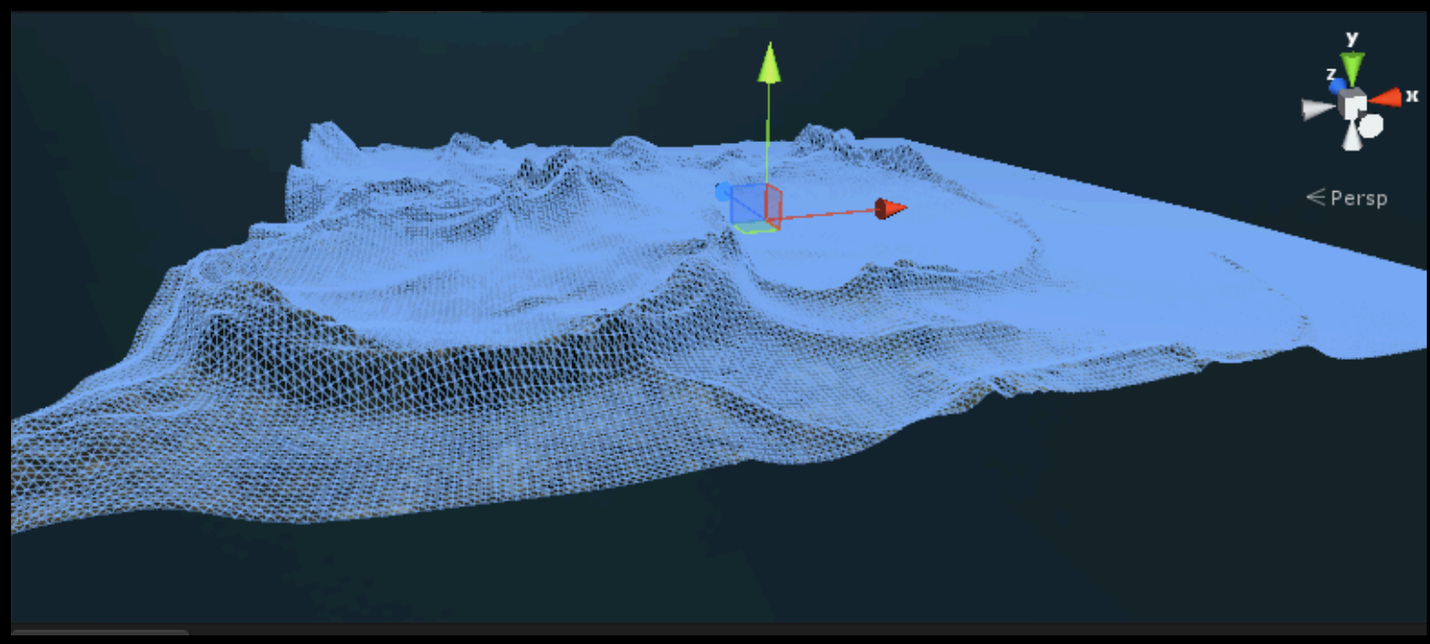


http://bugman123.com/FluidMotion/index.html

See some more fluid motion simulations



http://forum.unity3d.com/threads/water-simulation-directx-11-competition-entry.166810/



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

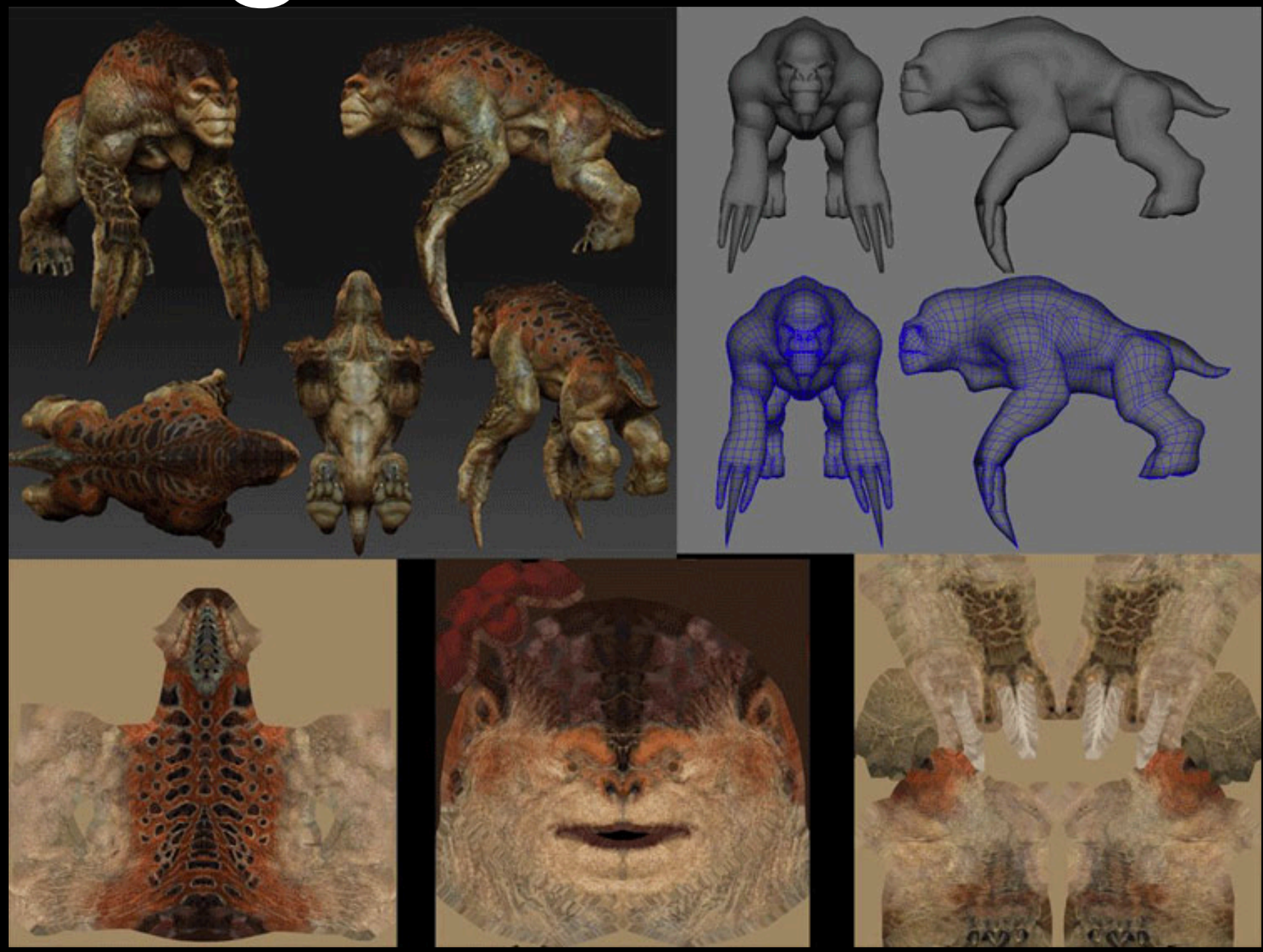
Putting it all together

Seeing behind the special effects:

https://www.youtube.com/watch?v=MnQLjZSX7xM

Application of 3D Modeling

Films, games, simulations



http://www.thegnomonworkshop.com/news/2013/03/why-a-camera-is-a-texture-artists-best-friend/

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

A nice review of the 3D Production Pipeline!

Reconstructions

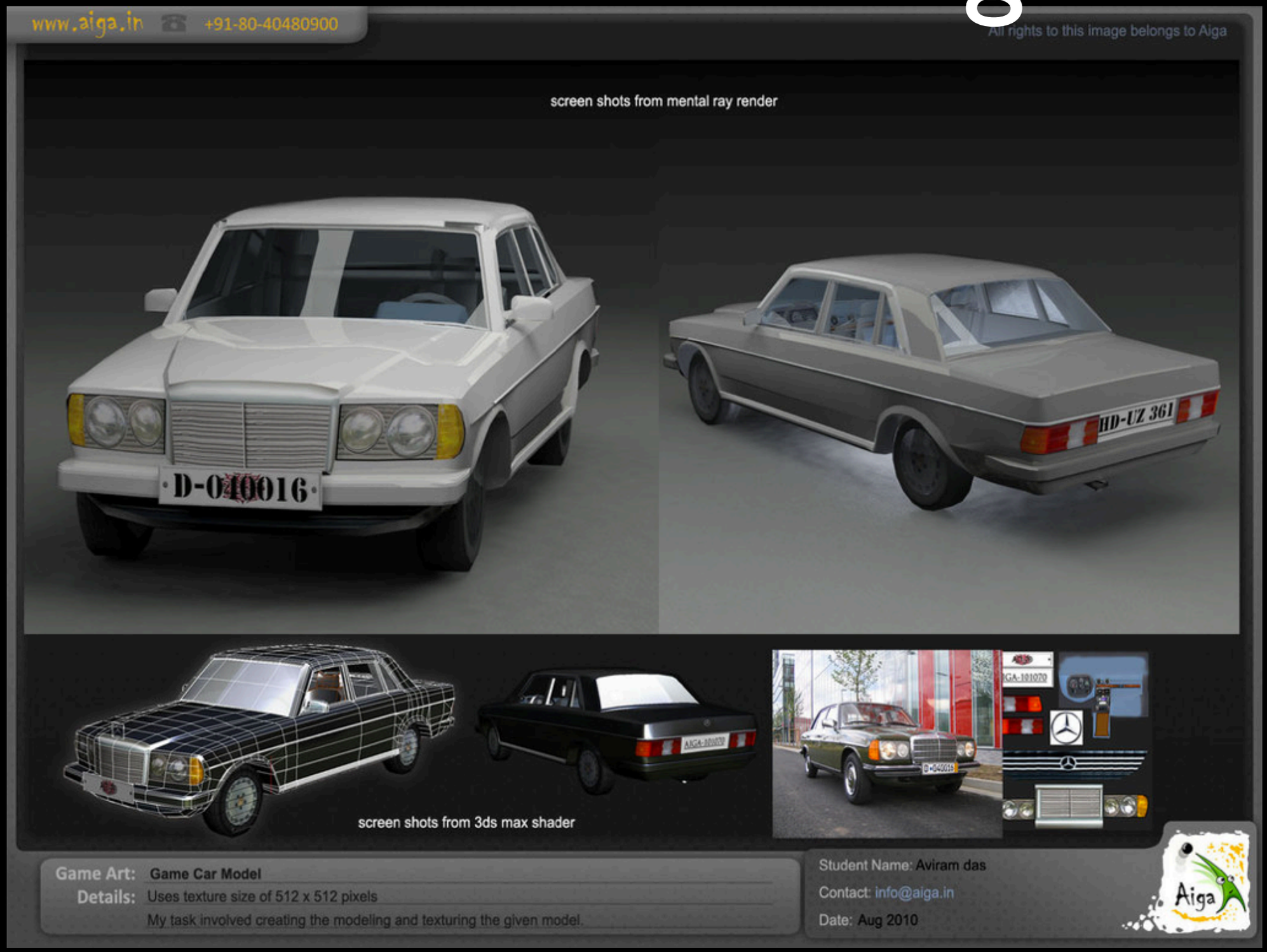
http://www.cs.mcgill.ca/~rwest/wikispeedia/wpcd/wp/f/Forensic_facial_reconstruction.htm

Learn more about forensic face reconstruction

http://news.nationalgeographic.com/news/2005/05/photogalleries/tut_mummy/index.html

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

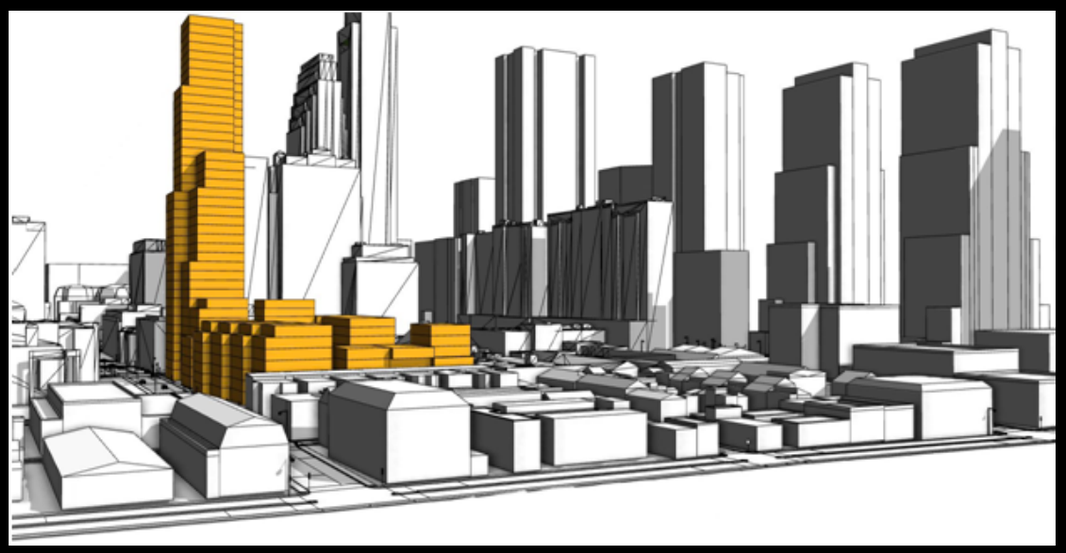
Product design



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

Urban Planning

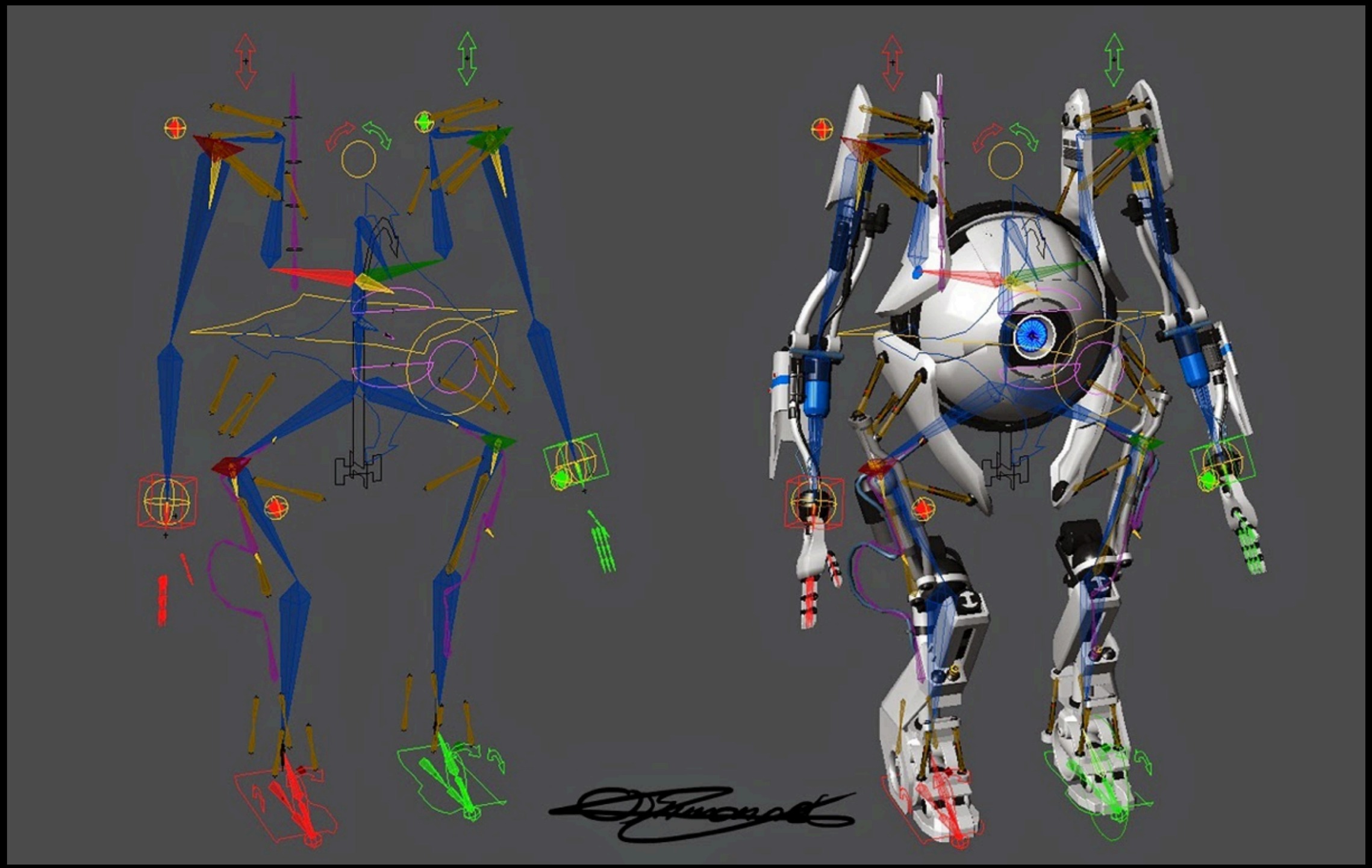
https://www.youtube.com/watch?v=a0dD2nRAGuM



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

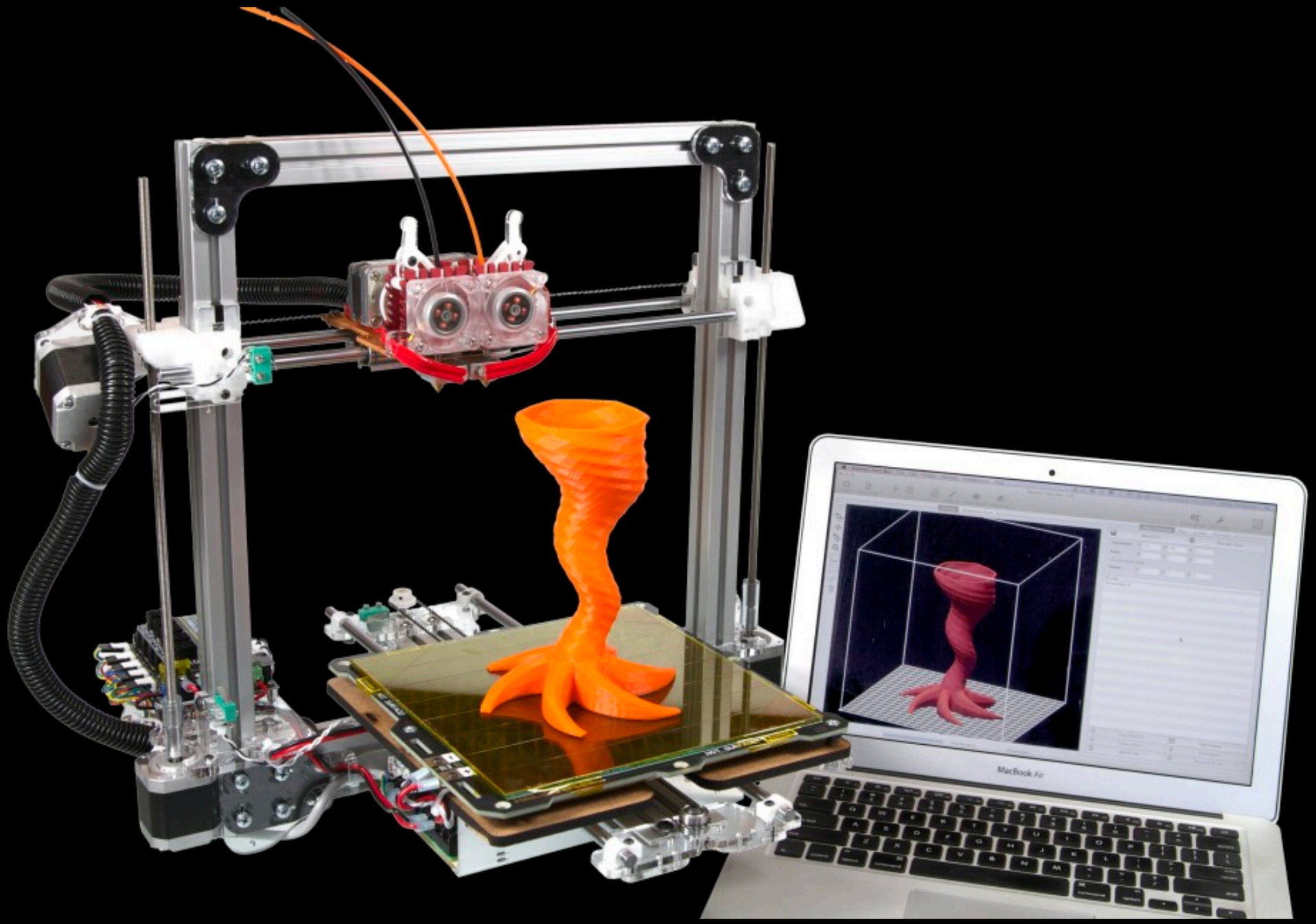
https://desktop.arcgis.com/en/cityengine/latest/get-started/overview-cityengine.htm
http://www.slideshare.net/elemky/esri-cityengine-minecraft-engaging-citizens-in-3d-city-planning

Robotics



https://kaylah3dmodelling.wordpress.com/2015/03/04/rigging/

3D printing



http://deezmaker.com/bukobot/

Learn more!

And the other links sprinkled throughout the slides!

- Khan Academy's "Pixar in a box": https://www.khanacademy.org/partner-content/pixar
- Math behind Pixar Ted Talk: http://ed.ted.com/lessons/pixar-the-math-behind-the-movies-tony-derose
- 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/
- Rigging examples: http://www.cgsociety.org/news/article/1537/rigging-reel
- A short introduction to computer graphics: http://people.csail.mit.edu/fredo/Depiction/1_Introduction/reviewGraphics.pdf