Deriving 3D Models from 2D Images, and Vice Versa:

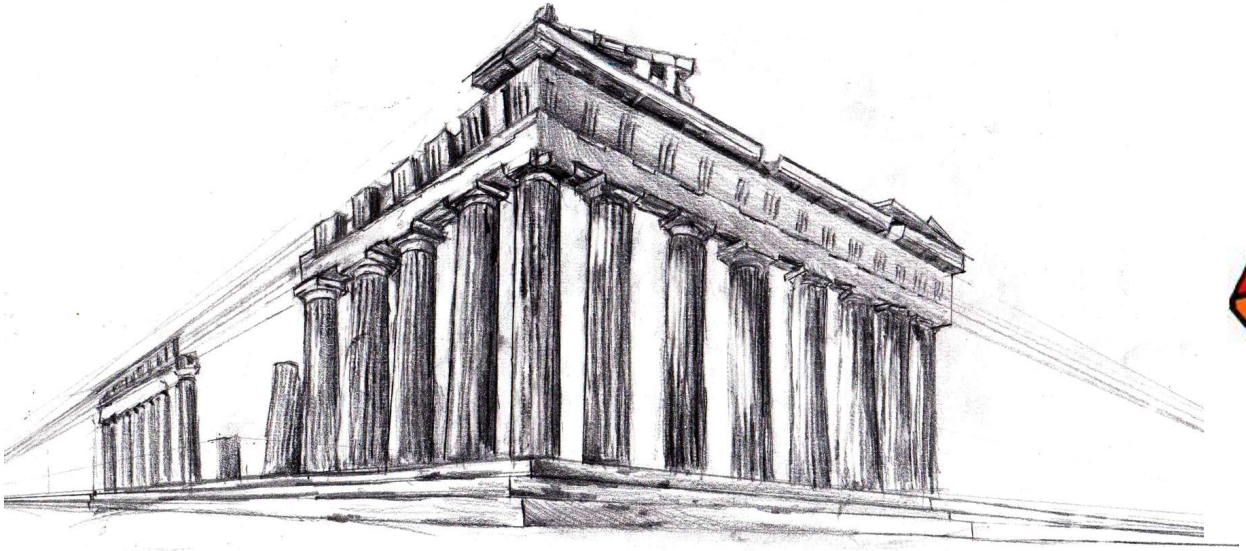
From Puzzles to Real Applications

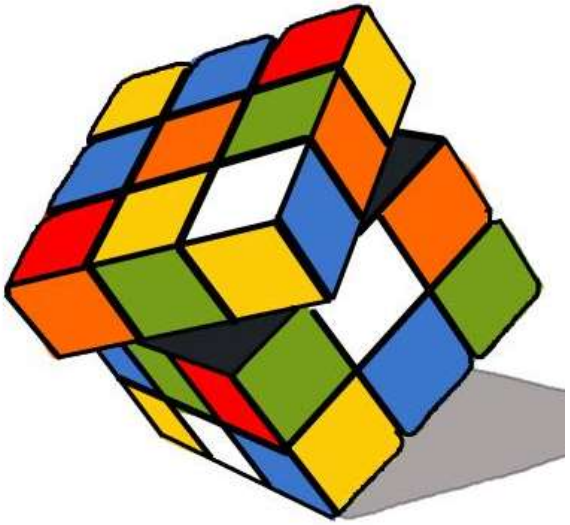
About This Presentation

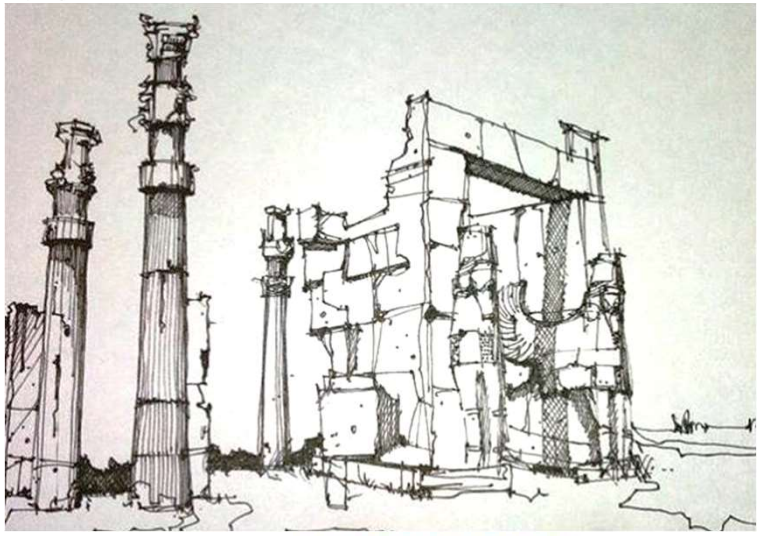
This presentation belongs to the lecture series entitled "Puzzling Problems in Science and Technology," devised for a ten-week, one-unit, freshman seminar course by Behrooz Parhami, Professor of Computer Engineering at University of California, Santa Barbara. The material can be used freely in teaching and other educational settings. Unauthorized uses, including any use for financial gain, are prohibited. © Behrooz Parhami

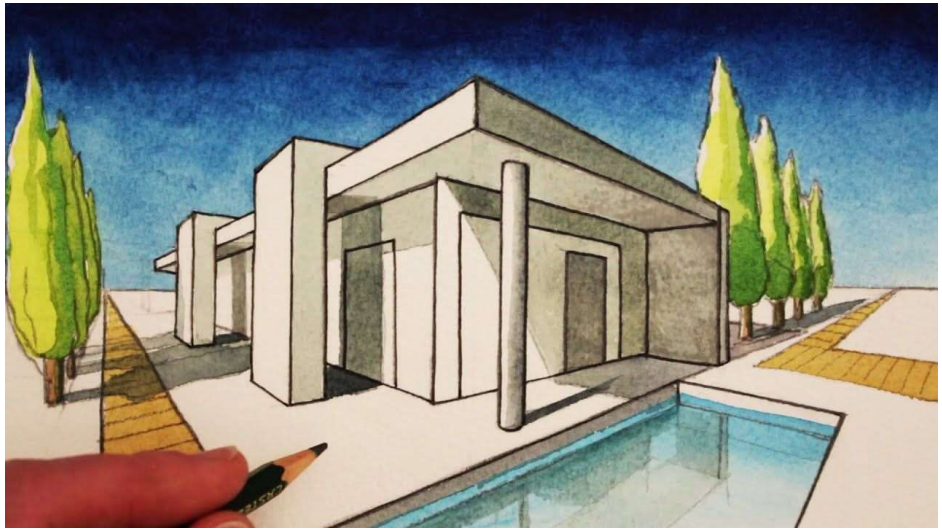
Edition	Released	Revised	Revised	Revised	Revised
First	Oct. 2016	Oct. 2018	Sep. 2020		

Perspective Drawings: Ancient and Modern



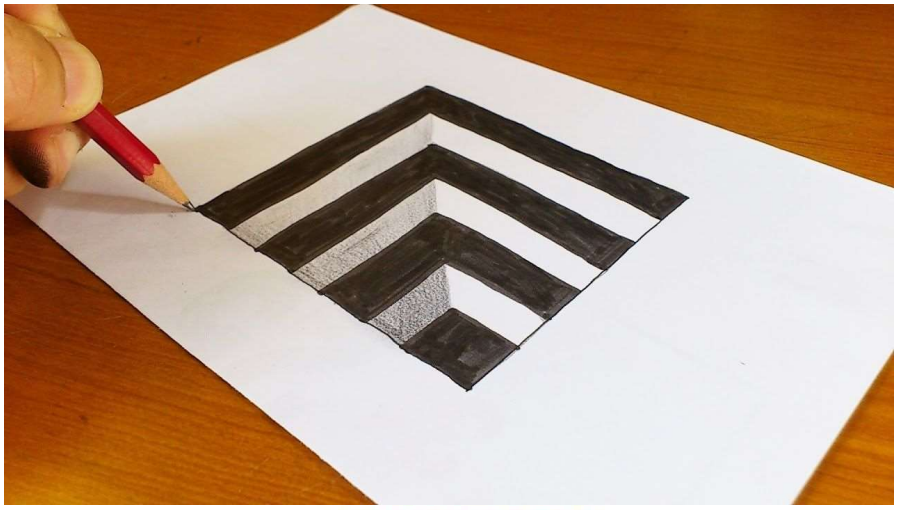






Evolution Has Programmed Us to See in 3D

Not only do we see this photo in 3D, but we extrapolate to fill in missing details, using visual cues, common sense, and general knowledge



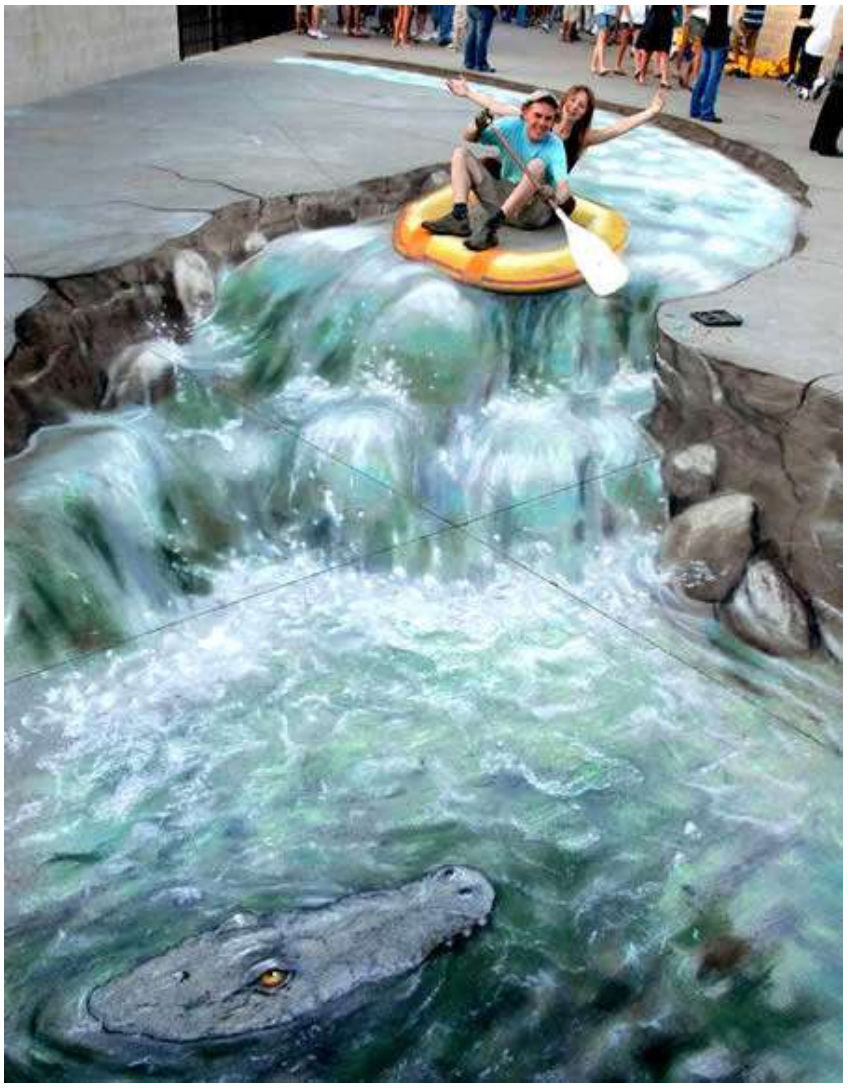
- Intuition can lead us astray
- Imprecision is a problem

3D Optical Illusions

How to create a 3D illusion: Hole on palm of hand

2-minute video: http://www.youtube.com/watch?v=s2LrmAThAhk

3D Optical Illusions: Sidewalk Art



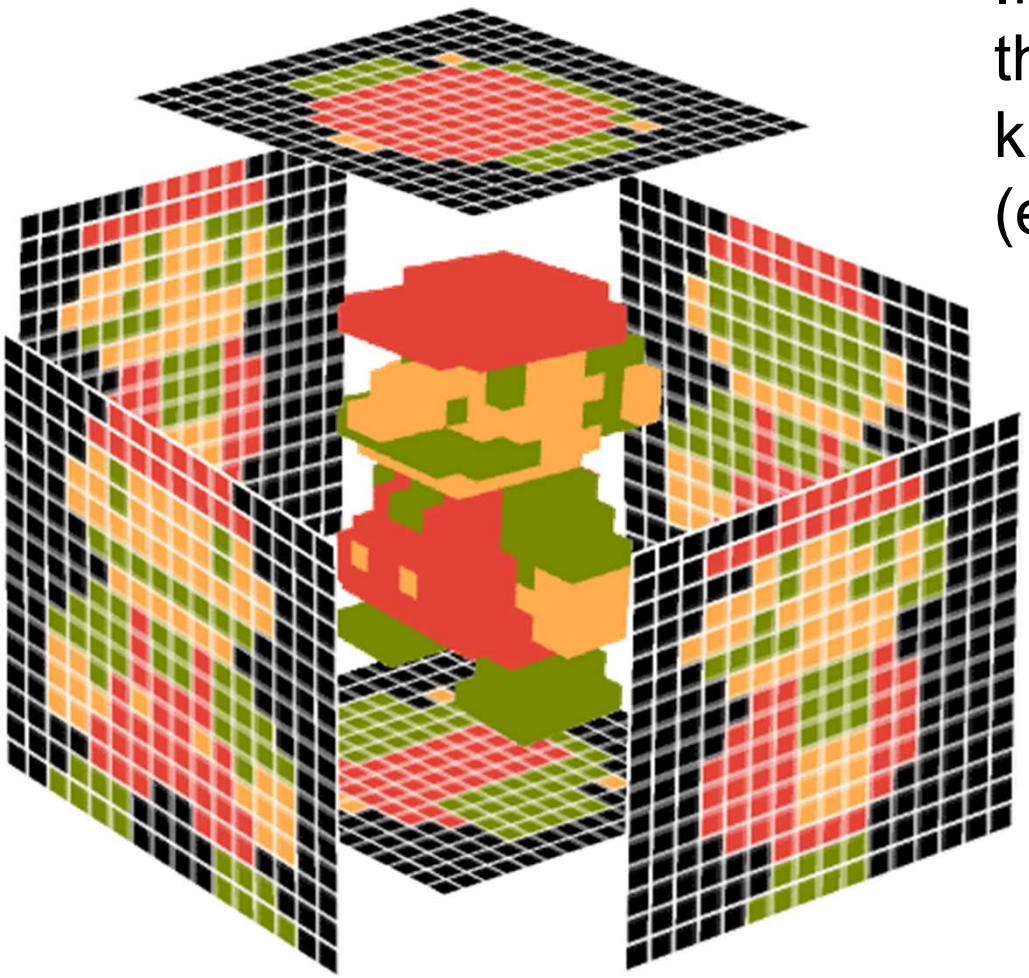
Intriguing 3D Objects (1)

Impossible World: A sculpture
by UK artist James Hopkins
(actual object, looks impossible)

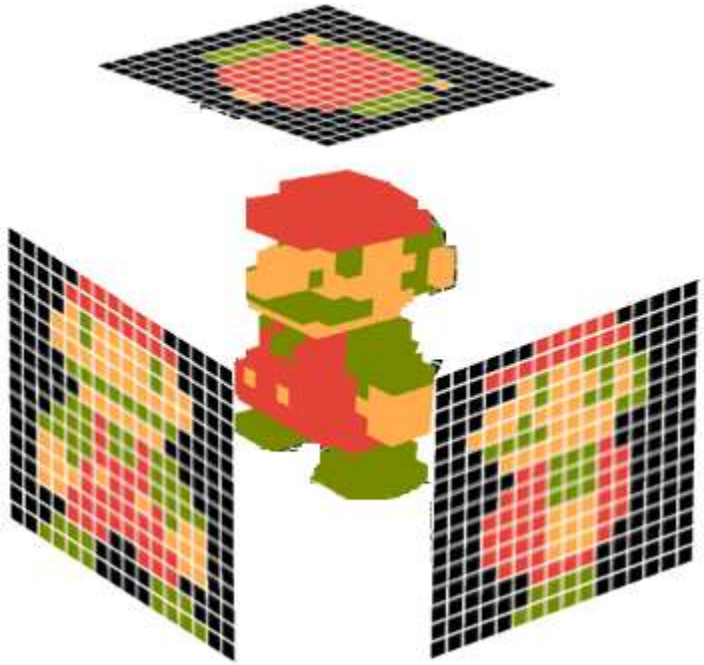
Intriguing 3D Objects (2)

Threshold: A sculpture created by UK artist James Hopkins (installed in Prague) looks like the digits 1, 2, or 3 depending on the viewing angle

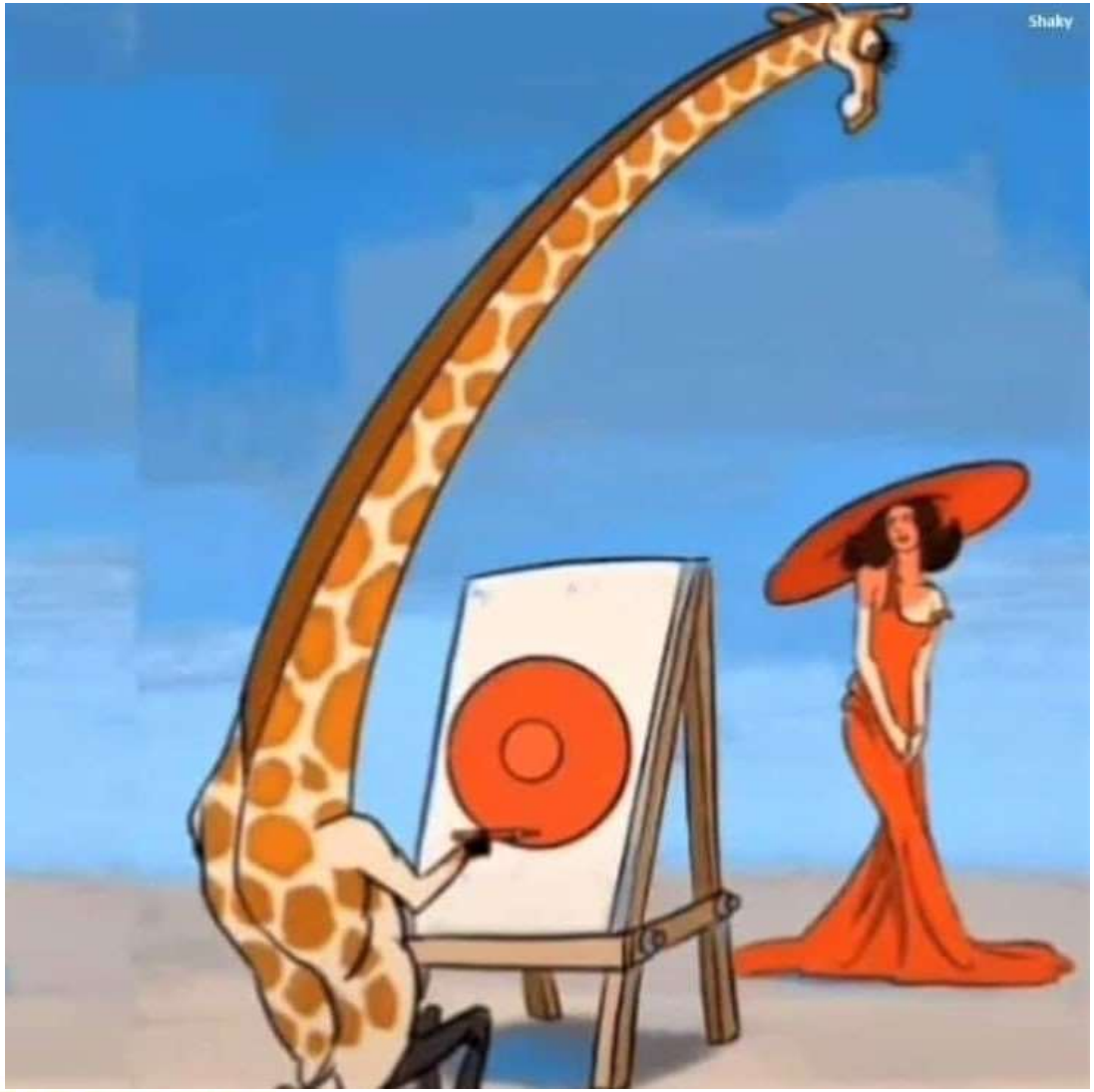
A 3D Object's Six 2D Projections



If we were to manufacture this object, we also need to know about its insides (e.g., is it hollow or solid?)



Things Become Simple with the Right Viewpoint



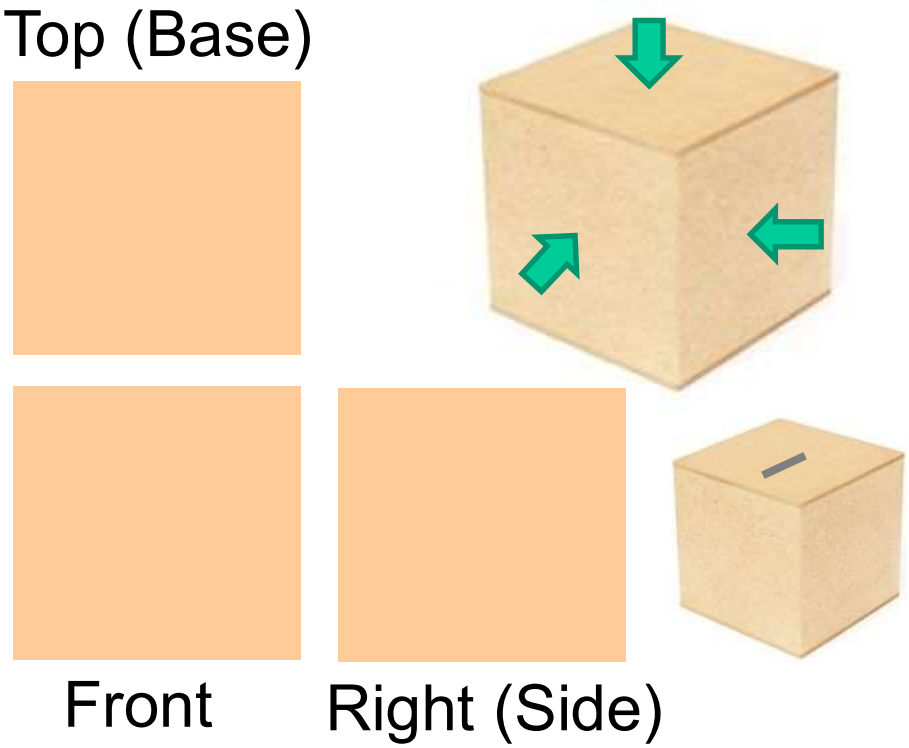
3D Structures Built of Cubic Blocks

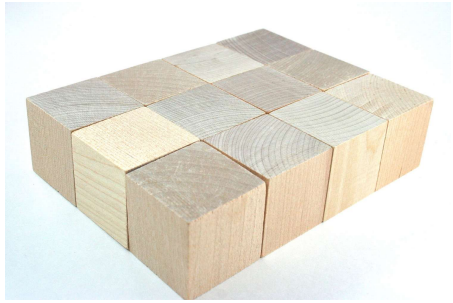
A 3D assembly of blocks can be specified by three views:

Top view (aka base view)

Front view

Right view (aka side view)

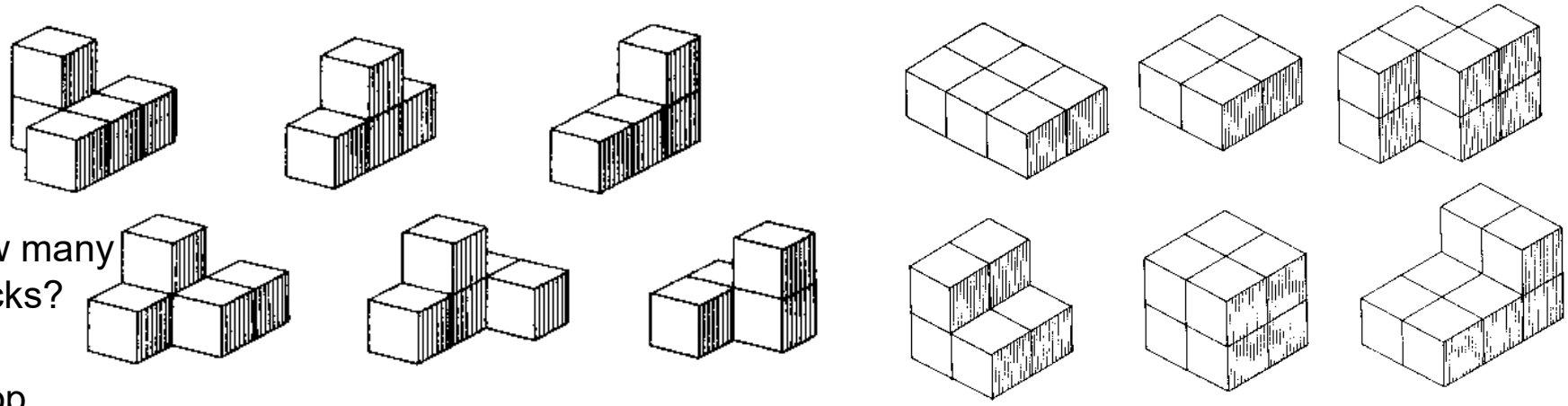




3D Structures Built of Cubic Blocks

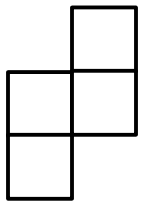
Draw the top, front, and right projections in two cases

1. Shapes formed from blocks; 2. Shapes carved out in one piece

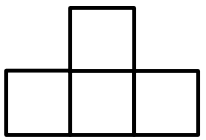


How many blocks?

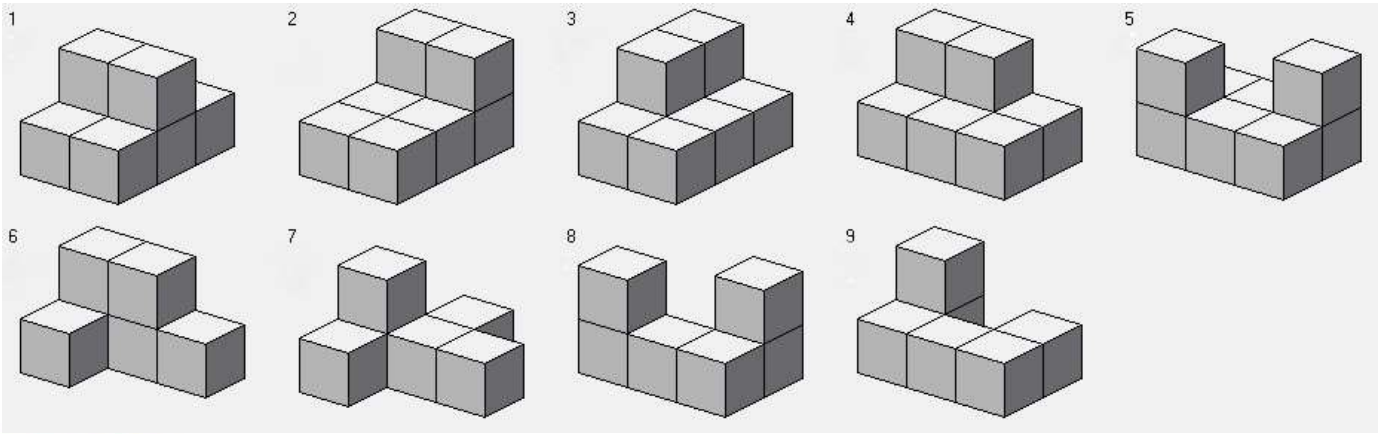
Top



Front

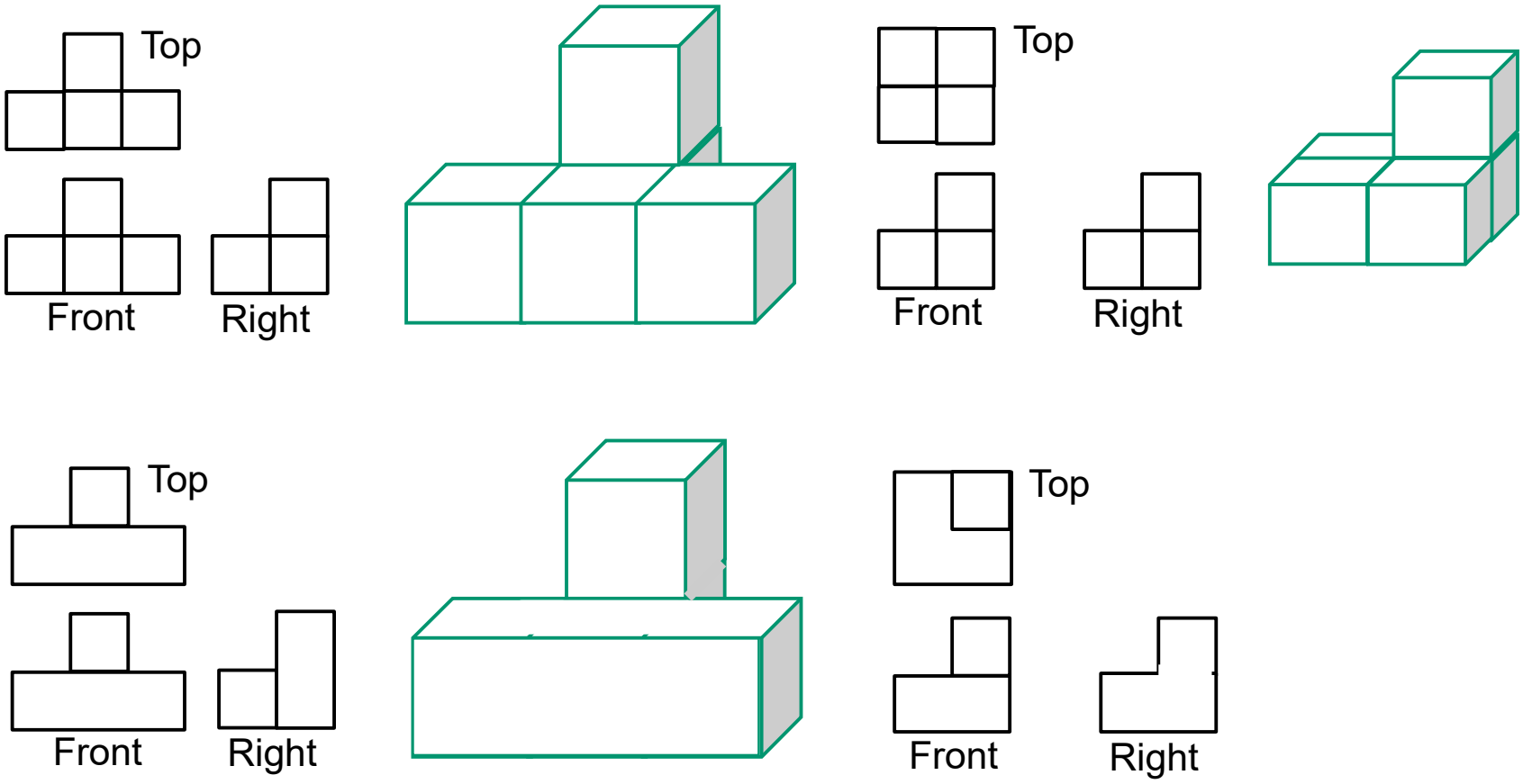


Right



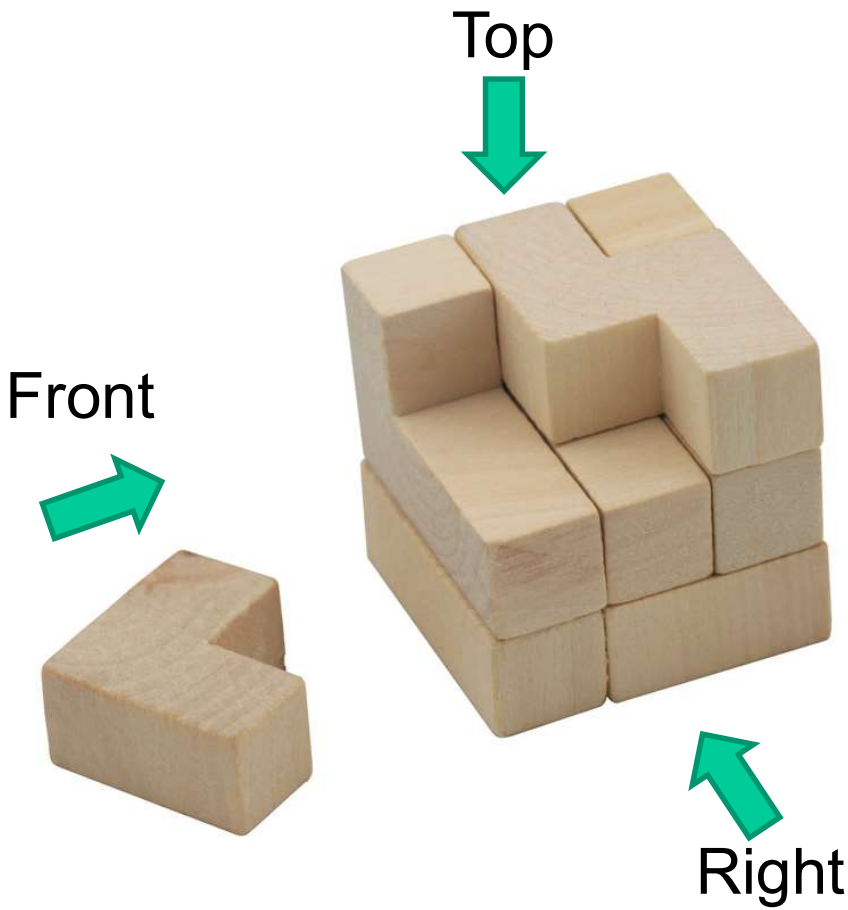
3D Reconstruction from 2D Projections

5-minute video: https://www.youtube.com/watch?v=PXp3D-R7--E



Challenge Puzzle 1: Draw the Three Views

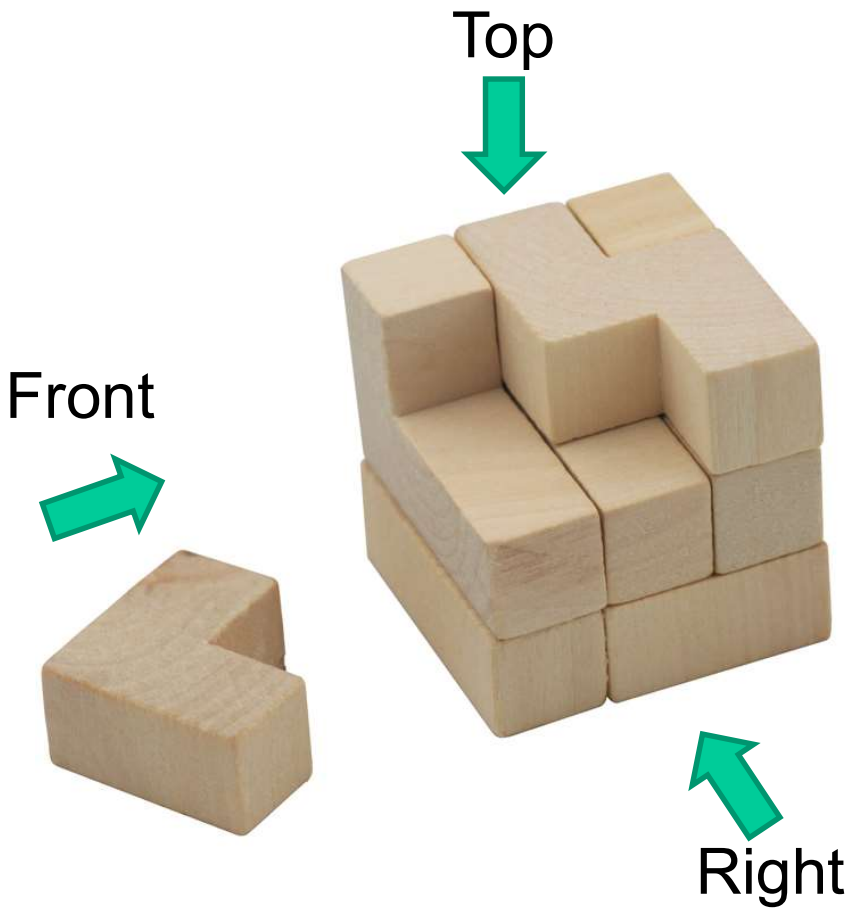
Draw once without and once with the removed piece

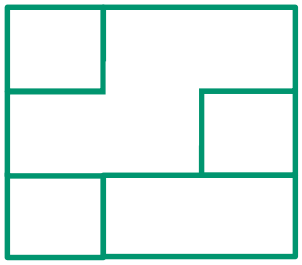


Draw the 3 views here

Challenge Puzzle 1: Three Views Answer

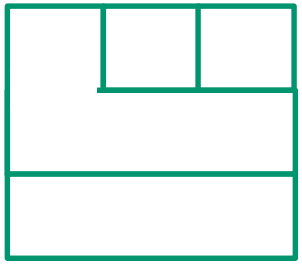
Draw once without and once with the removed piece



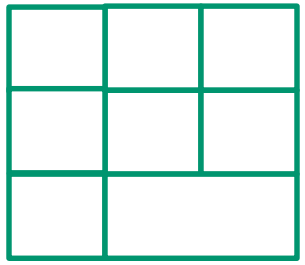


Top

Without removed piece



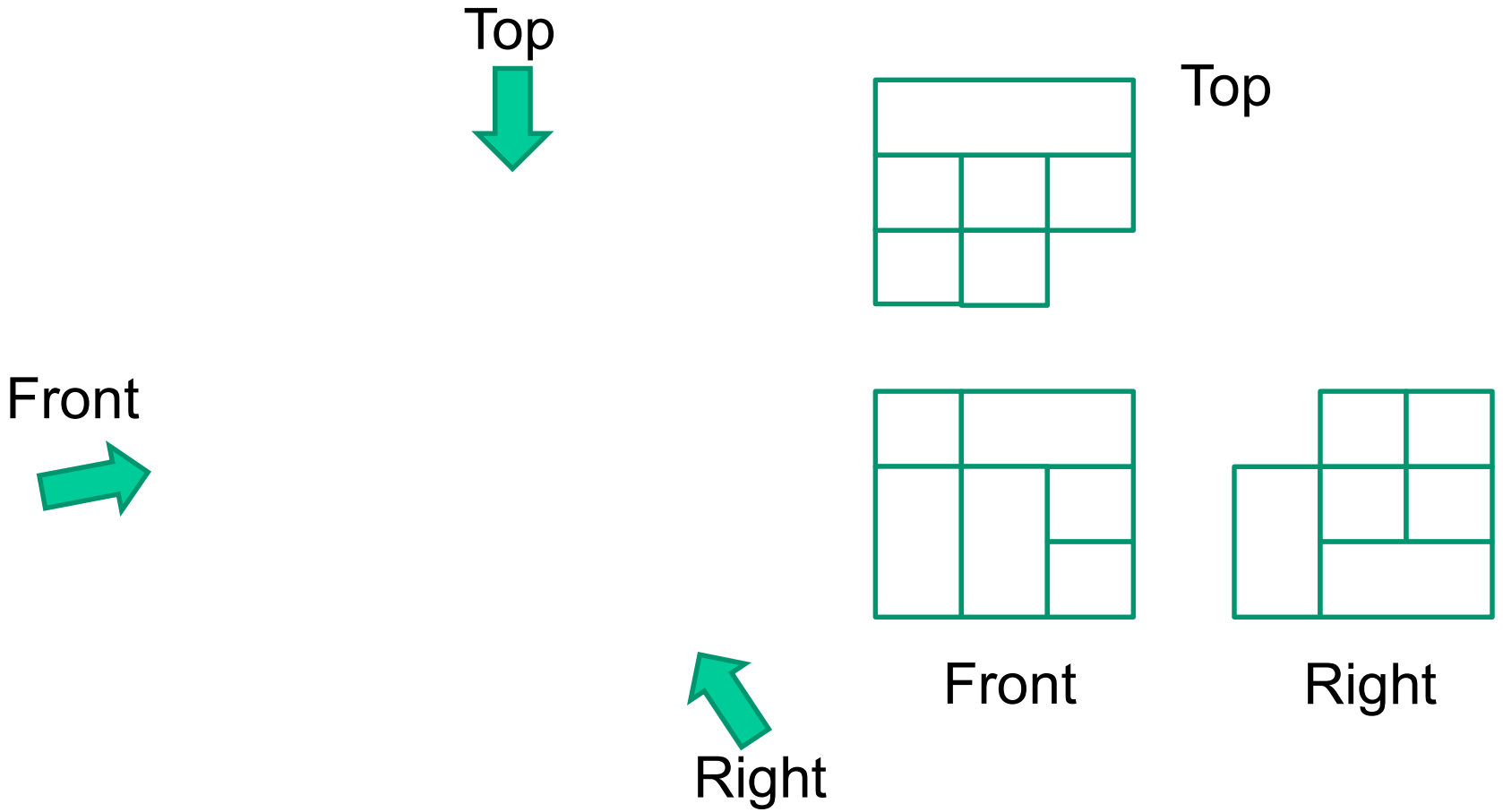
Front



Right

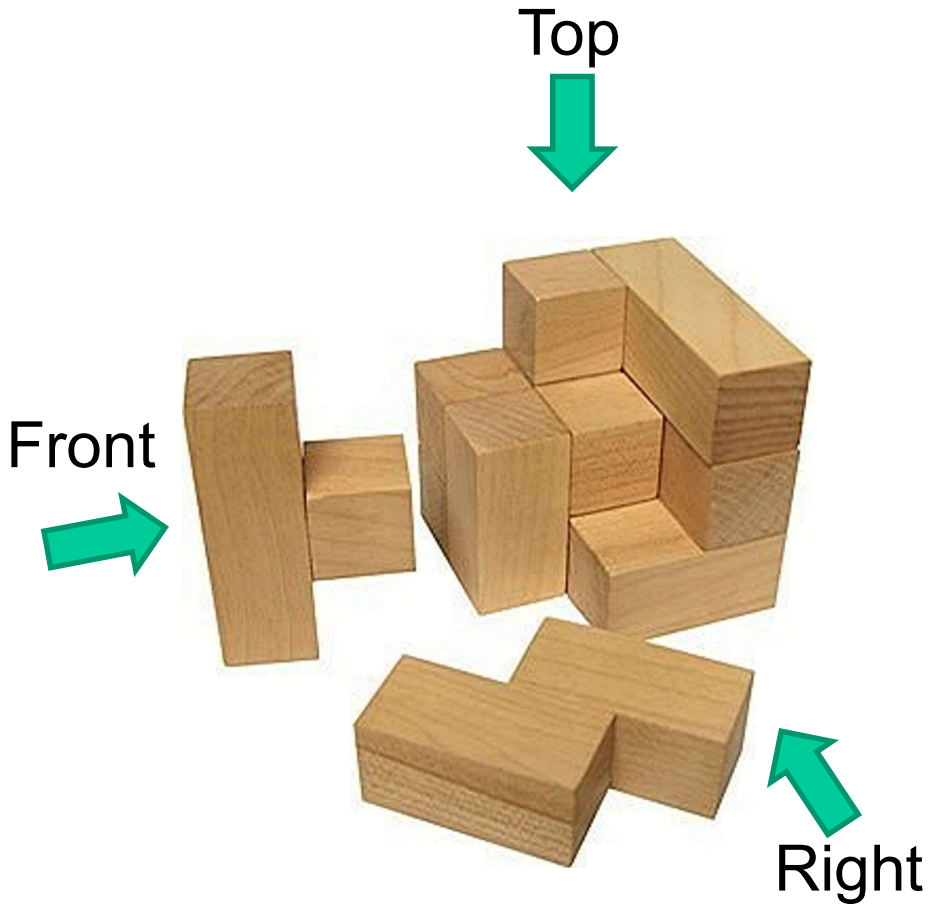
Challenge Puzzle 2: Derive the 3D Object

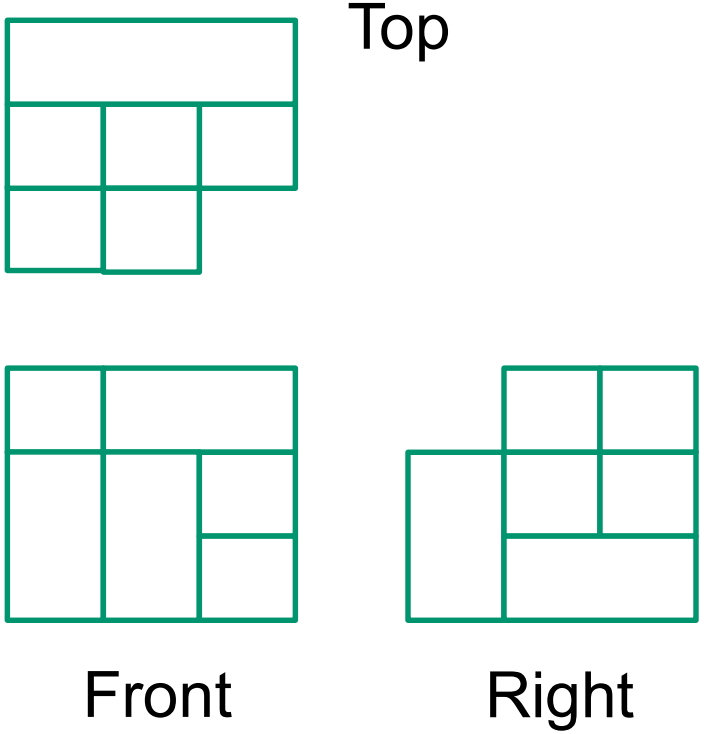
Is there a unique 3D arrangement of blocks with these 3 views?



Challenge Puzzle 2: 3D Object Answer

Draw once without and once with the two removed pieces

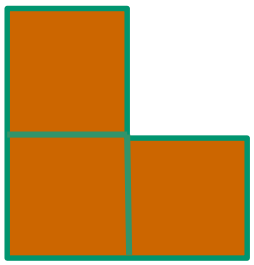


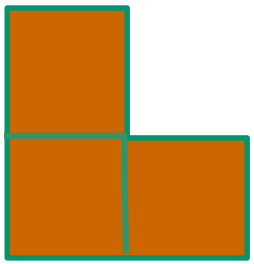


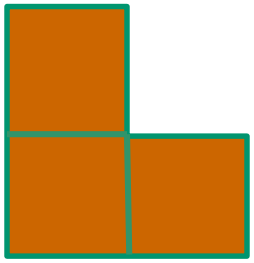
Comparing 3D Objects with 2D Projections

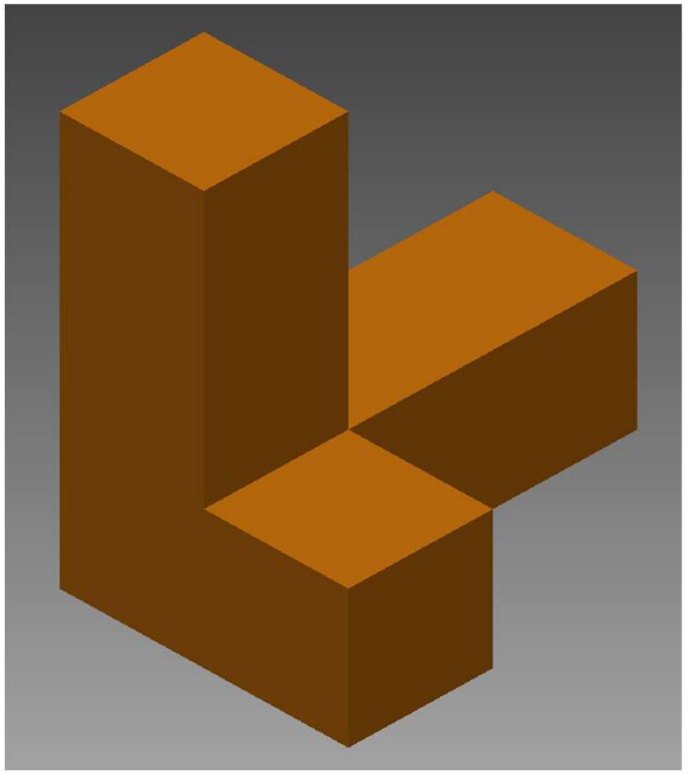
Are these two objects the same? If not, list the differences.

Change the projections so that they correspond to the 3D object

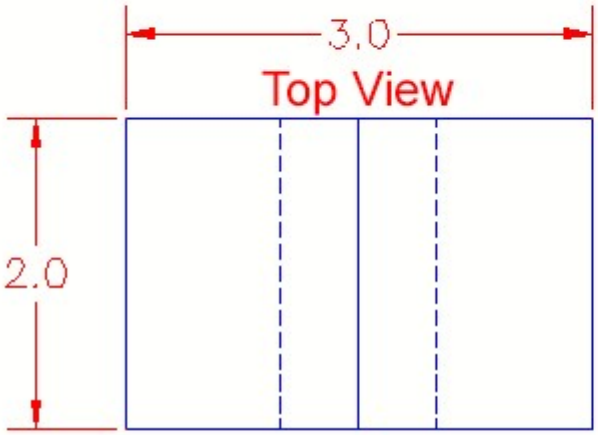


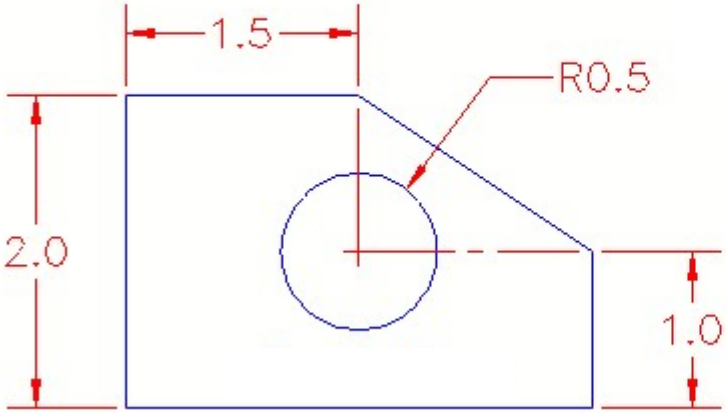


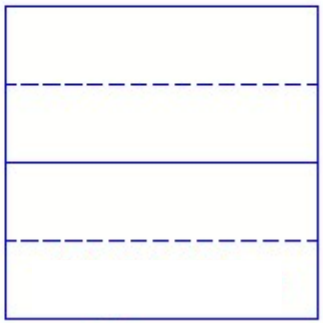




Engineering Drawings of a 3D Object



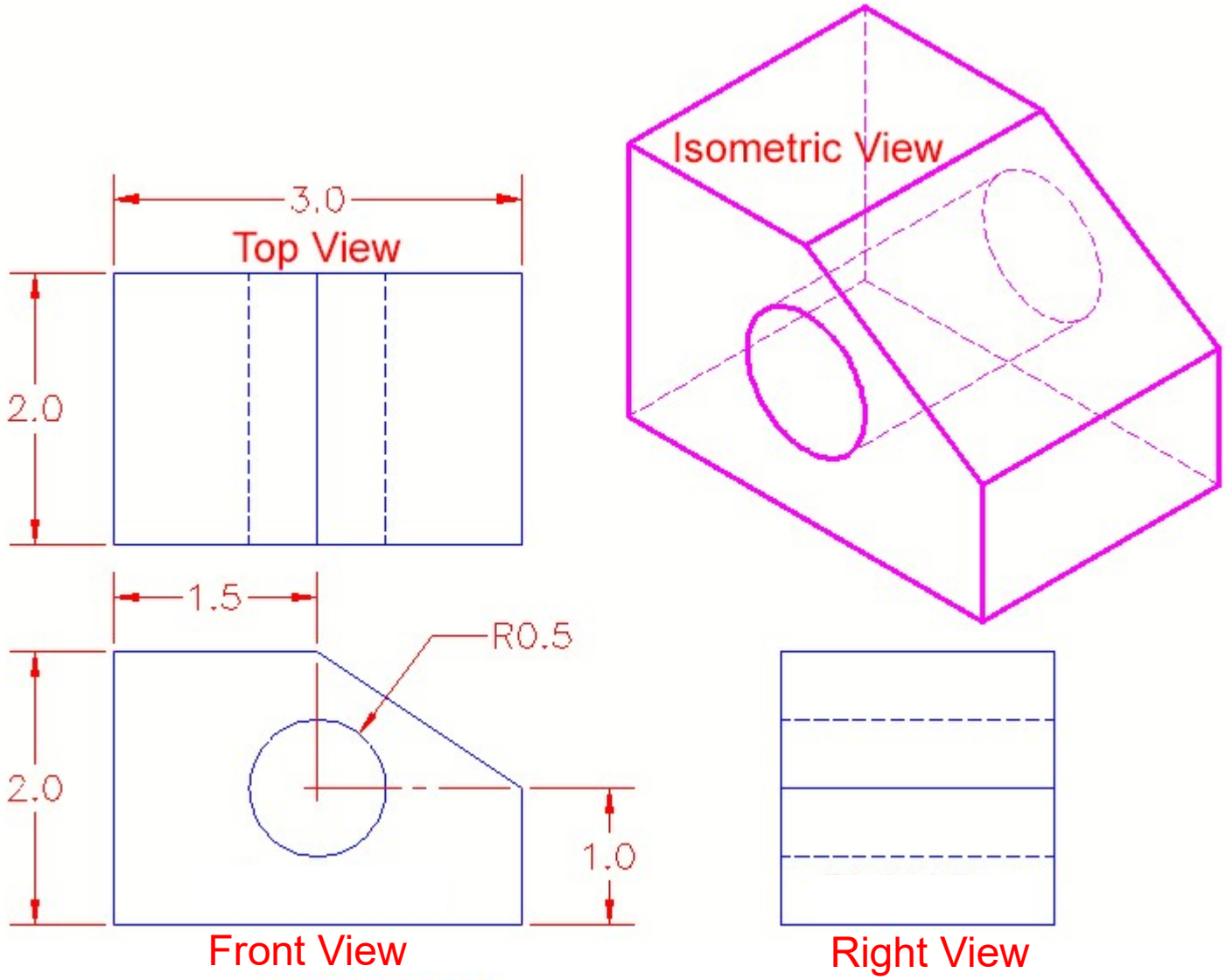




Draw the 3D object here

Dashed lines represent elements that are invisible in that view (i.e., they are on the back side or inside the object)

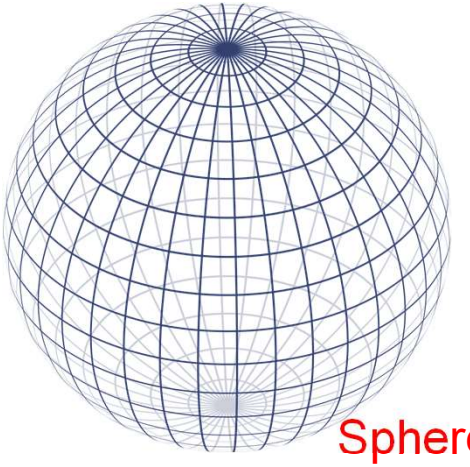
Engineering Drawings of A 3D Object



Hidden elements shown as dashed lines

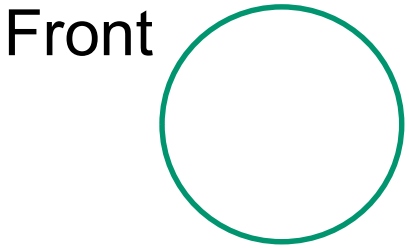
With no dashed lines, we couldn't tell how deep the hole is

When Three 2D Images Do Not Suffice

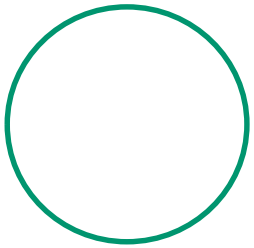


Sphere

Top

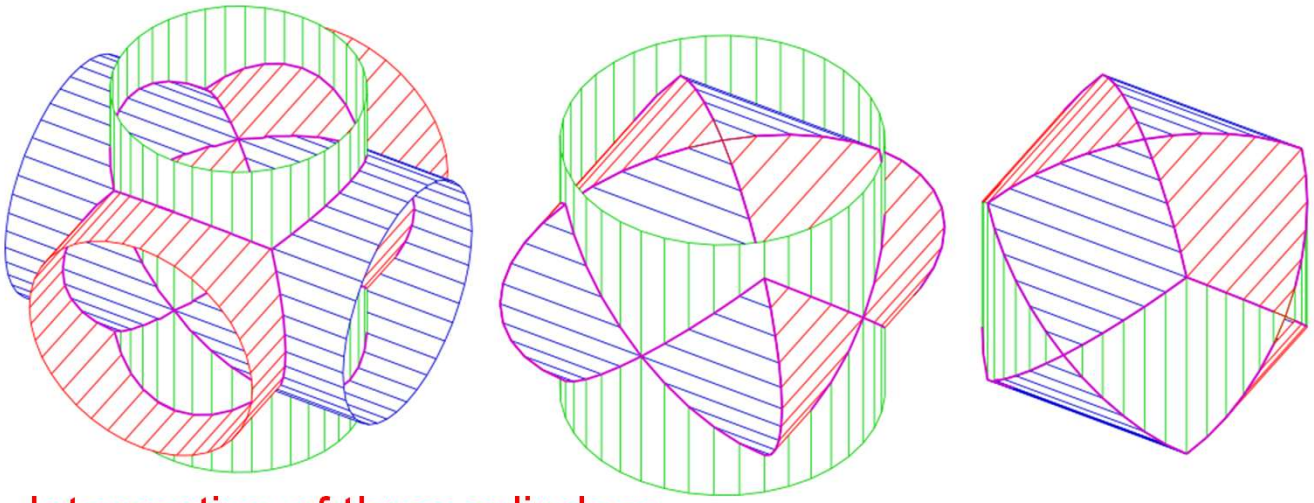


Front



Right

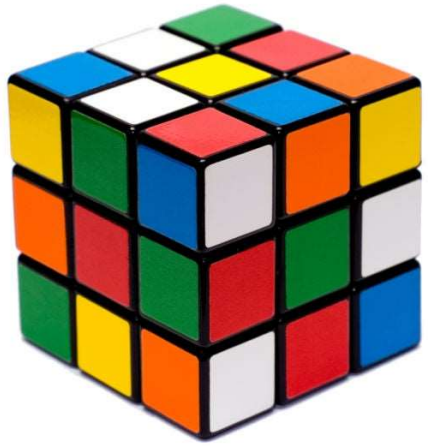
3D images from Wikipedia

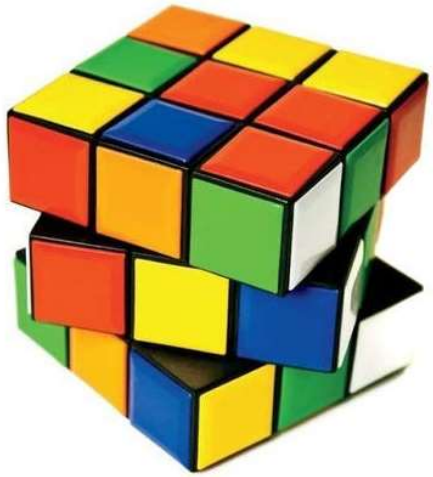


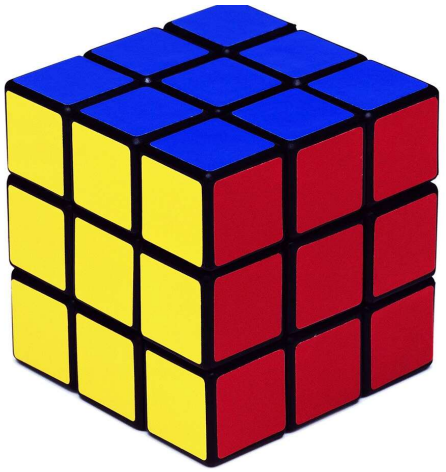
Intersection of three cylinders

Two different objects with the same three projections

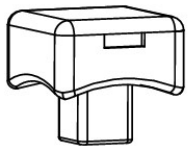
An Ingenious 3D Object: Rubik's Cube



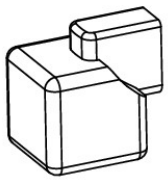




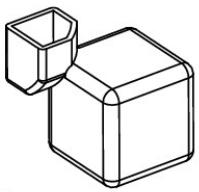
a Center shaft frame



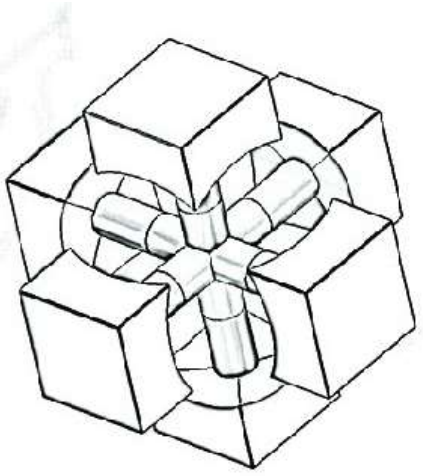
b Center piece



c Edge piece



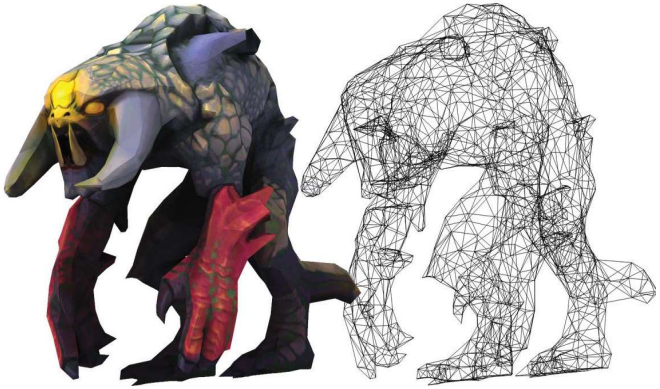
d Corner piece

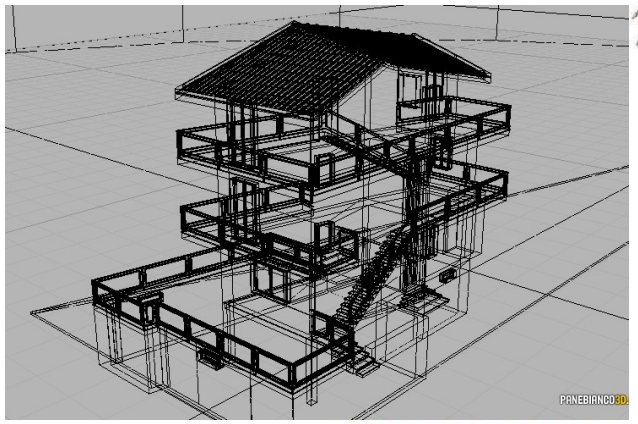


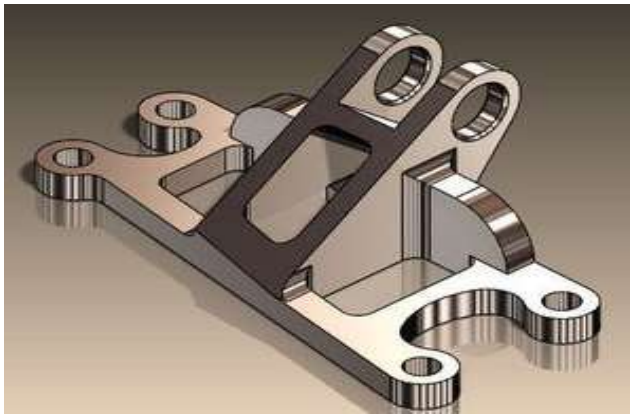
https://www.youtube.com/watch?v=bgcScY7CiMs

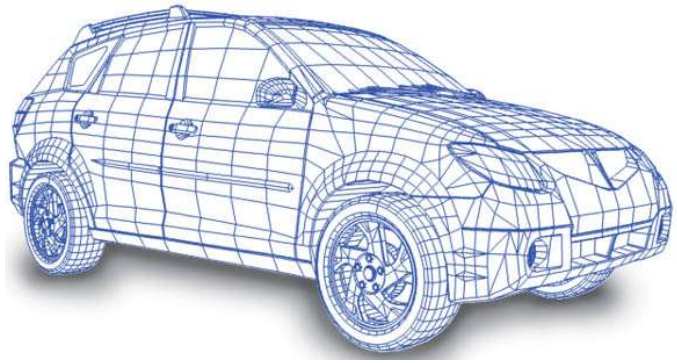
3D Modeling in Practice

3D models are needed everywhere:
Computer games | Architecture | Medical diagnostics
Industrial manufacturing (mechanical parts, cars, planes, …)









Computer Game Character Animation

Similar to animation for film, but here speed is more important

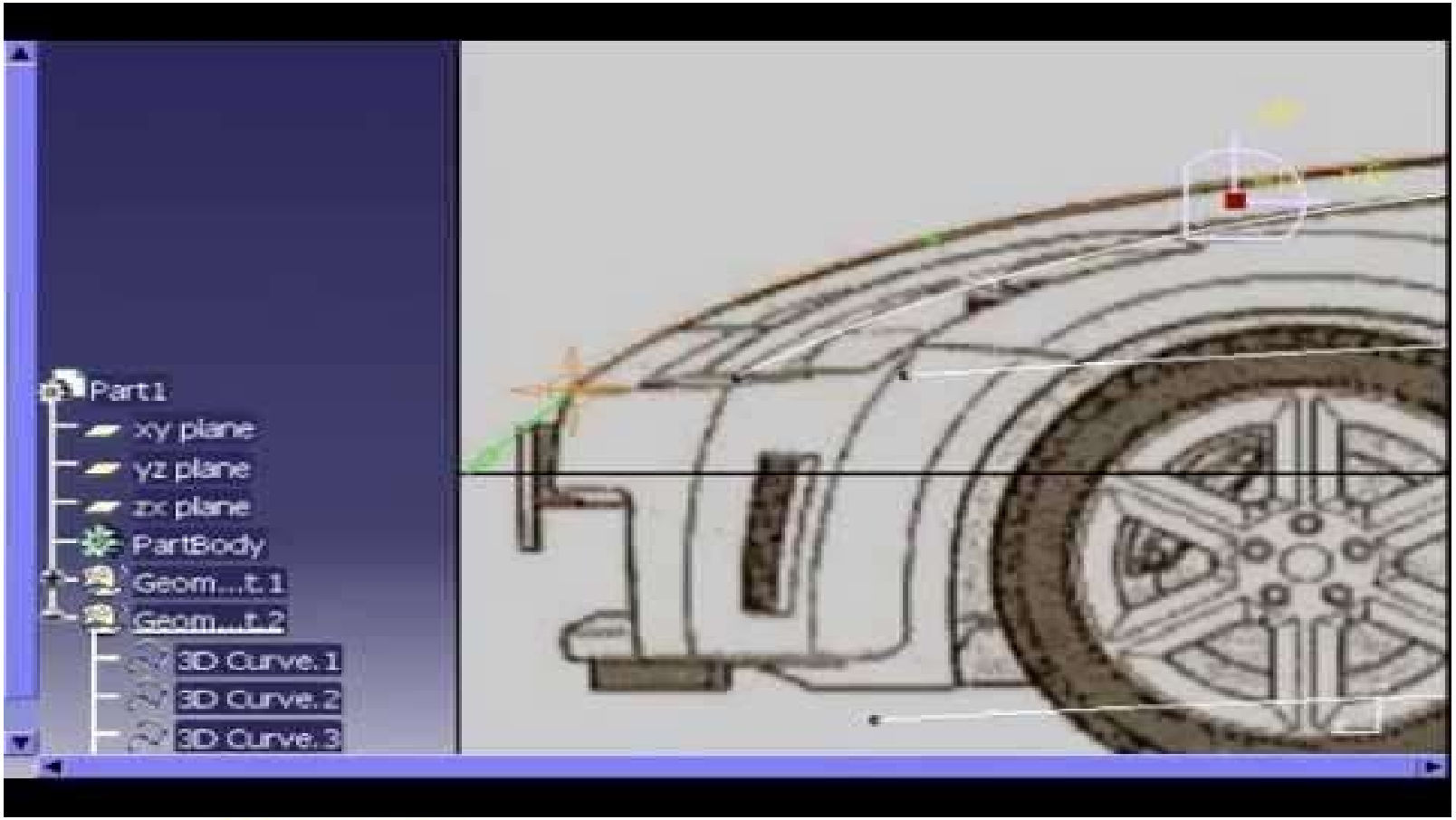
1-minute video (no longer available):
http://www.youtube.com/watch?v=yQuStfDbd9s

Modeling of Car Bodies in 3D

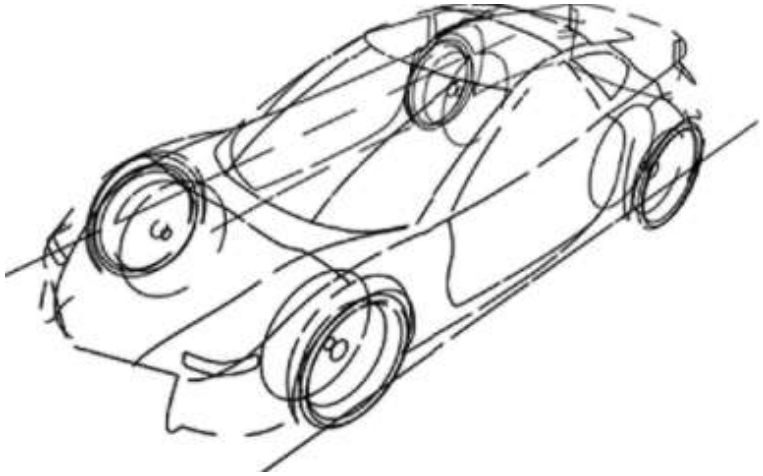
Car body represented as a large collection of polygons
Model consists of polygon shapes and their adjacencies

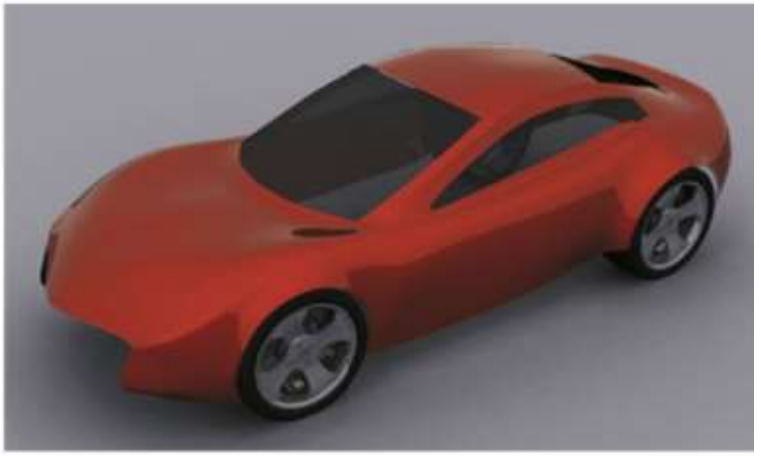
3D Modeling of a Car

Turning 2D views into a 3D model (video unavailable)
2-minute video: http://www.youtube.com/watch?v=uwvthq5ZD0o



Creating 3D Models from Sketches

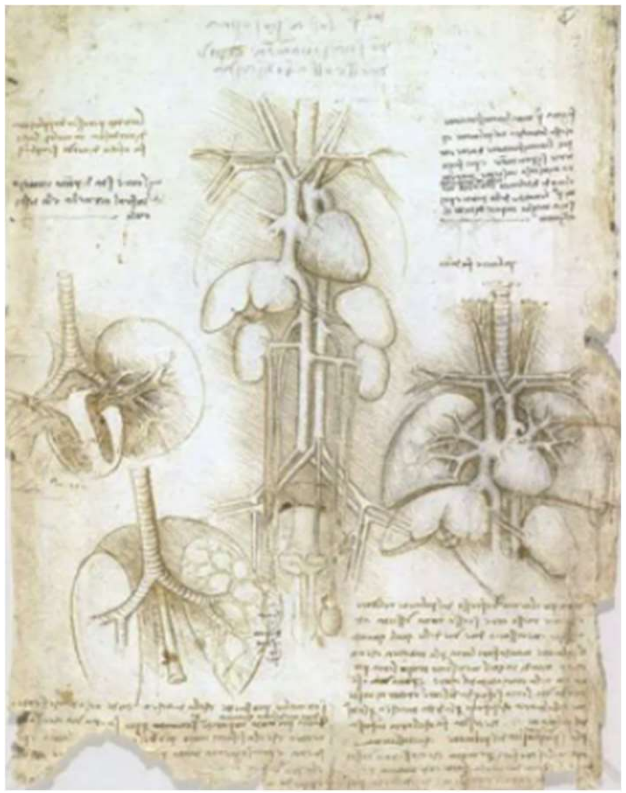




Michelangelo's Anatomical Sketchbooks

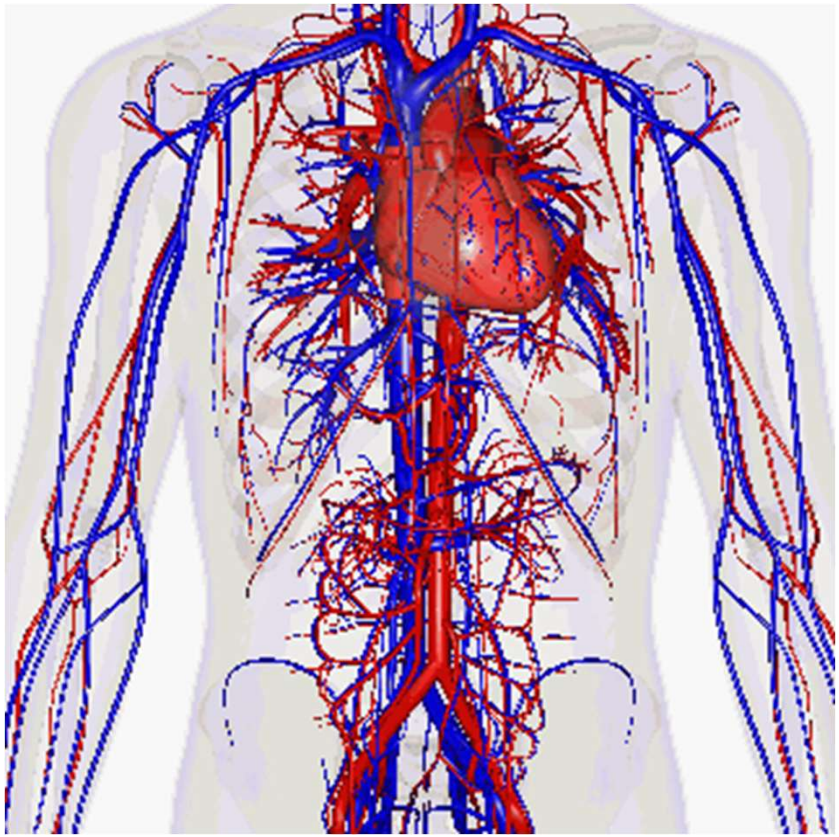
Learning proportions and forms (body in different positions)
Visualizing relations and placements of body parts

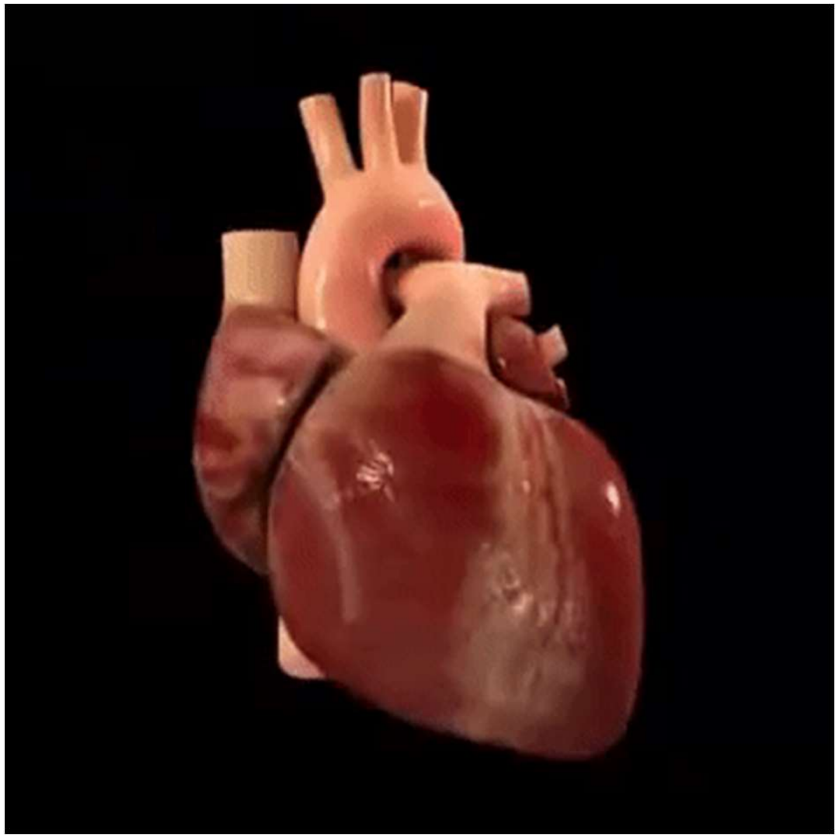
https://www.bbc.com/culture/article/20130828-leonardo-da-vinci-the-anatomist



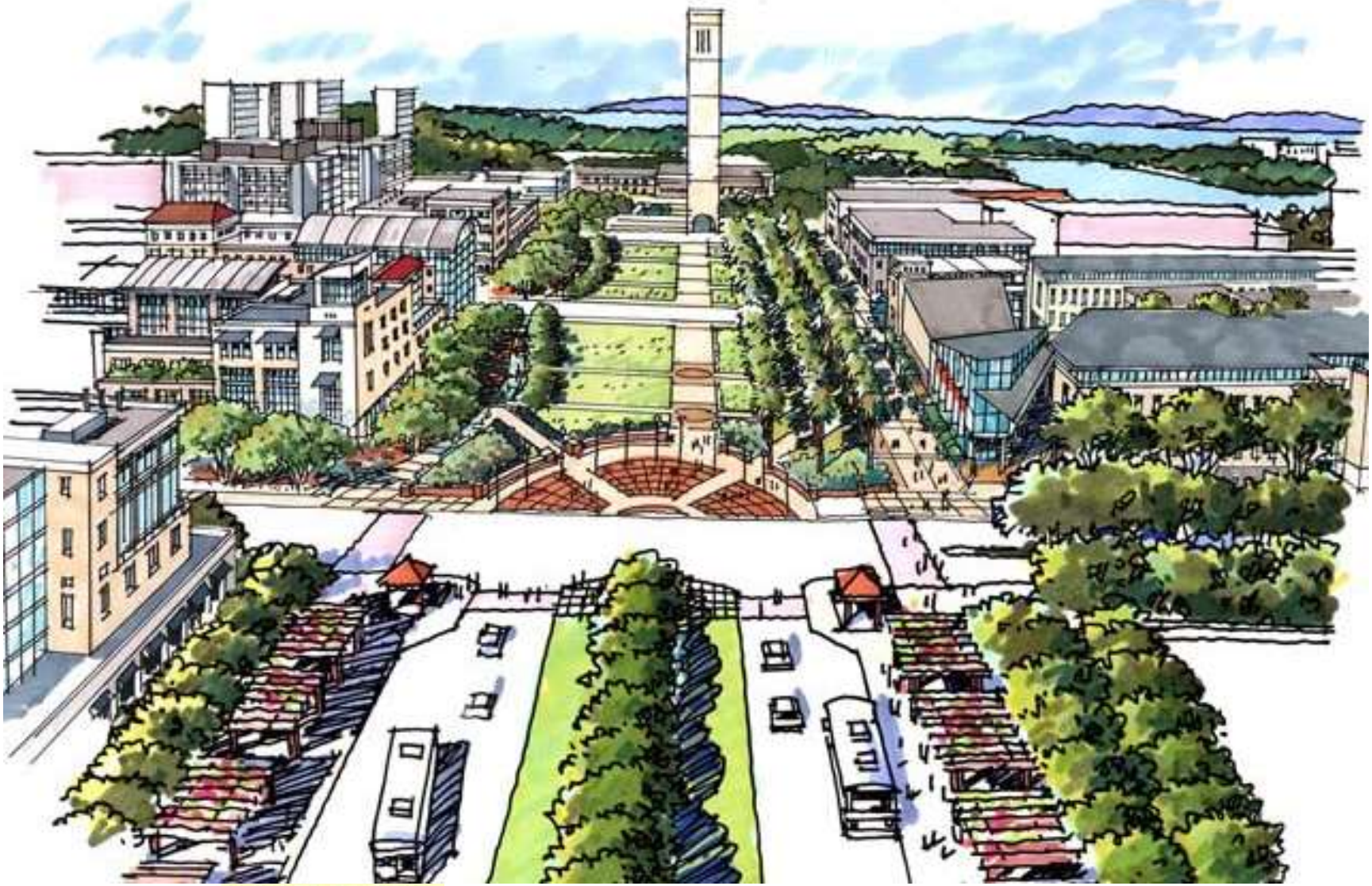
Modeling of the Human Anatomy

Used for anatomy education and medical-personnel training
Have replaced the use of cadavers for the most part





UCSB's Long-Term Development Plan



Virtual Architectural Preview

Residential complex viewed from different angles before it is built:
3-minute video: http://www.youtube.com/watch?v=_zeEiQfgicY

Modeling of Archaeological Sites

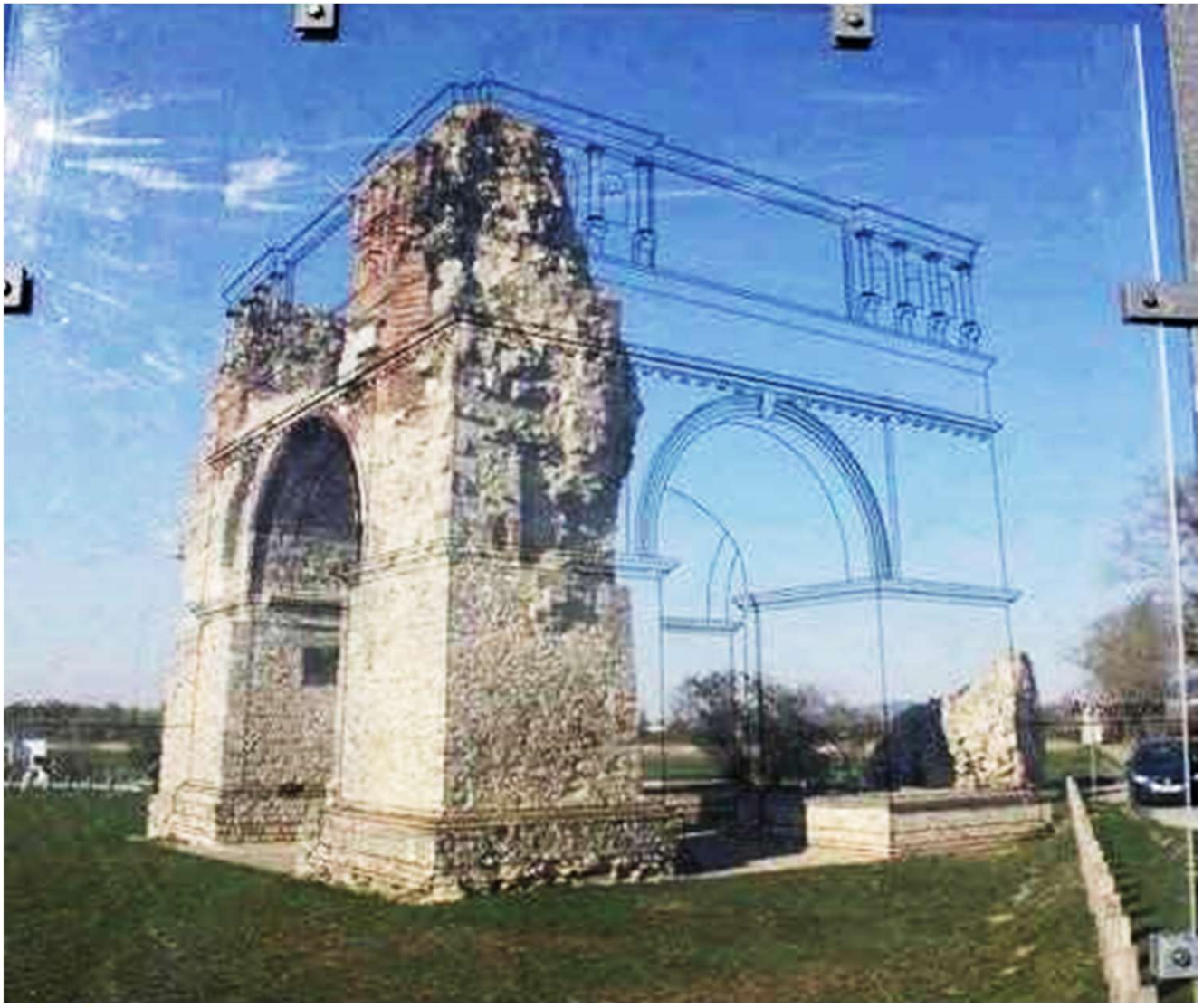
Study of ancient civilizations

Repair or reconstruction

Preservation of history (e.g., in the face of threats from ISIS/DAESH)

Illustrated tourist guides

Virtual tours



Virtual Reconstruction of the Temple Mount

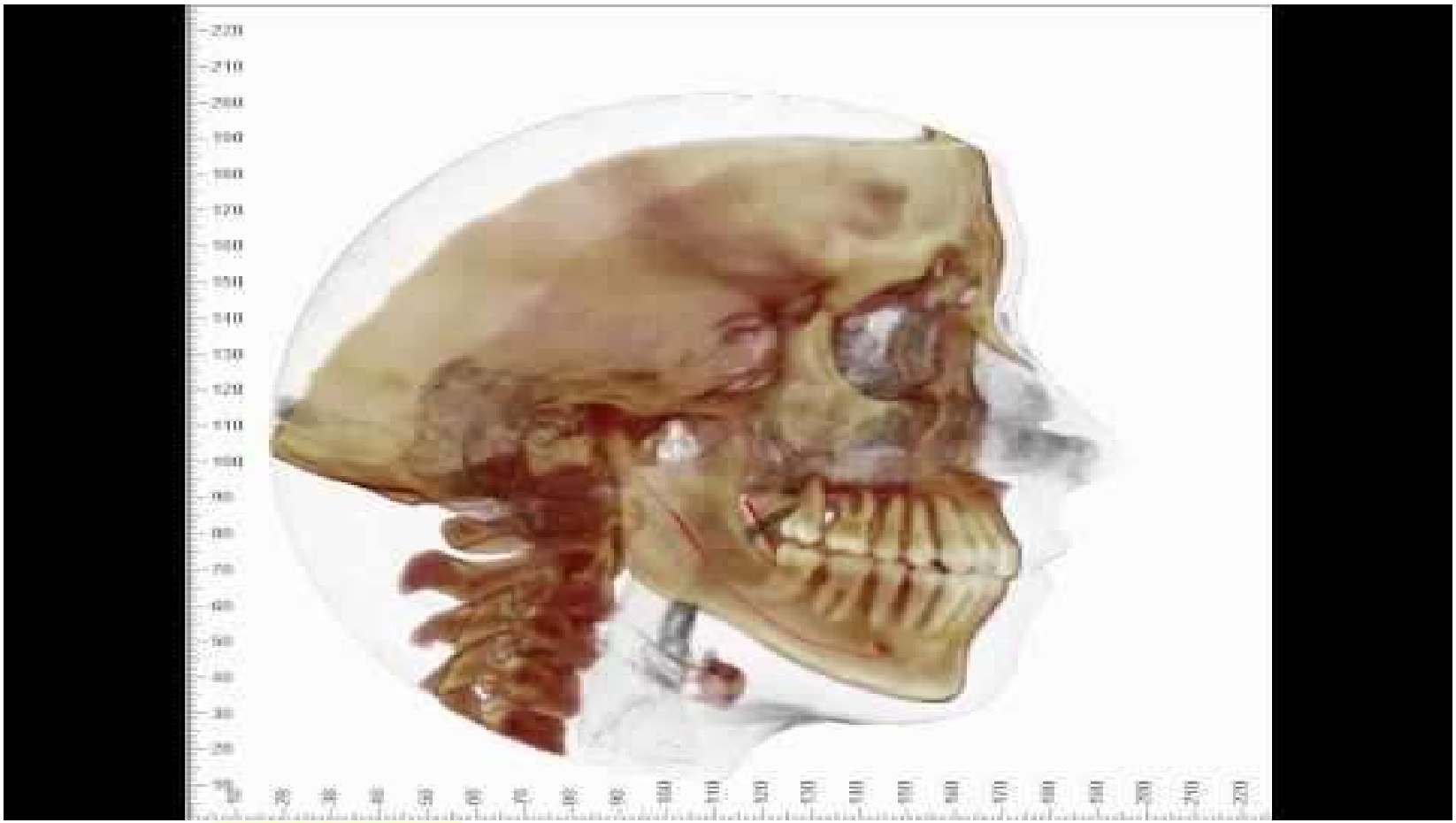
UCLA's Urban Simulation Team built a 3D computer model:
8-minute video: http://www.youtube.com/watch?v=HHLD6RXVLaM

Virtual Reconstruction of the Temple Mount

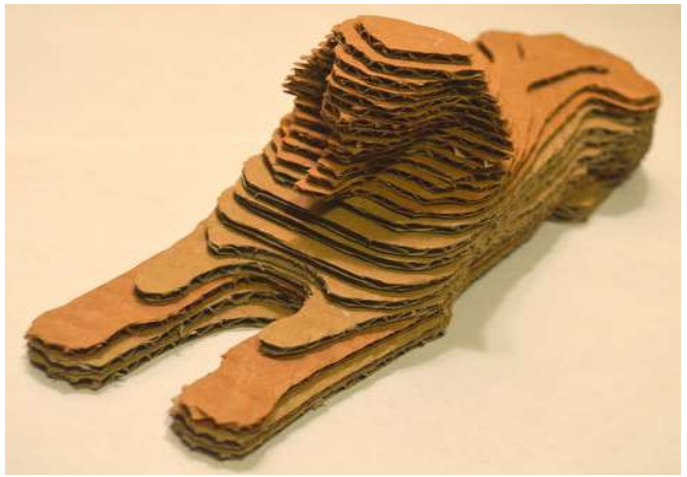
Virtual tour, of UCLA, with focus on athletic facilities:
9-minute video: https://www.youtube.com/watch?v=b24fKAC-d0w

3D Medical Imaging

Multiple 2D images (views or slices) turned into a 3D model.
1-minute video: http://www.youtube.com/watch?v=QeqzJbRgQx0



3D Model Built from Slices: Terrains, etc.

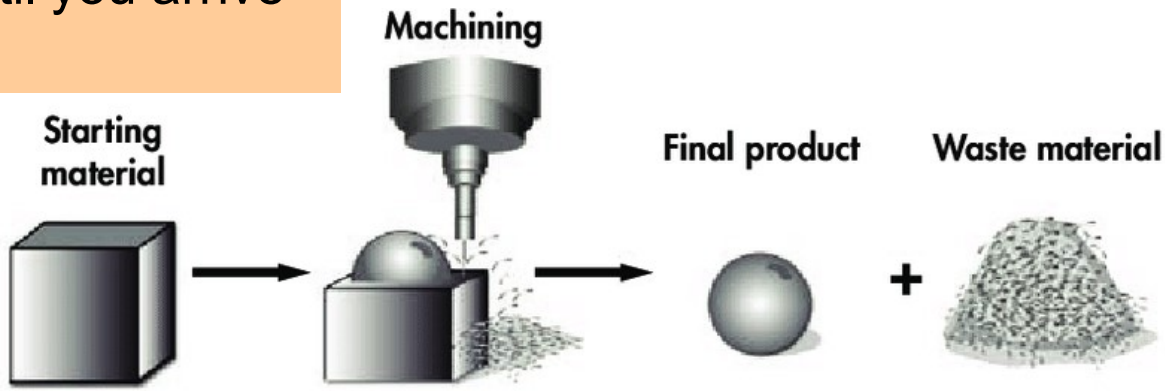


3D Model Built from Slices: Human Body

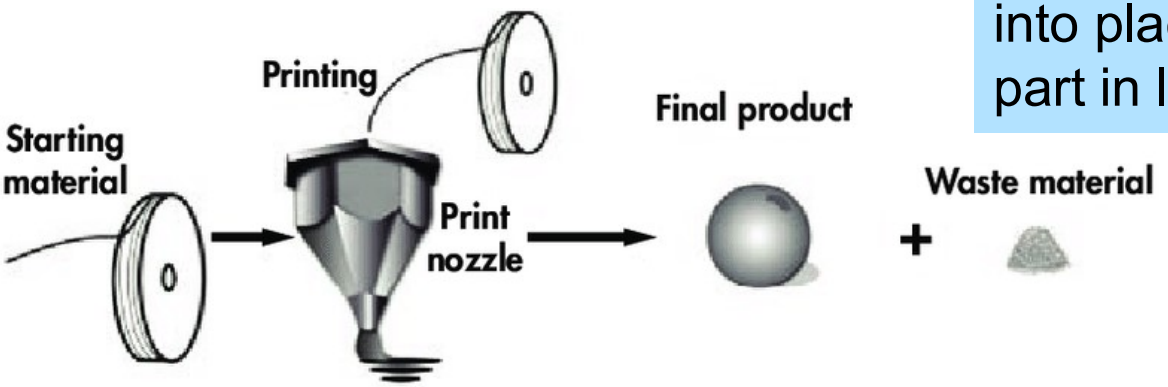
Darth Vader's head assembled from slices
2-minute video: http://www.youtube.com/watch?v=S2G2ySEaJso

Subtractive vs. Additive Manufacturing

Subtractive: Start with a bigger piece of raw material and gradually remove the un-needed parts, until you arrive at the desired shape



Additive: Material is guided into place, to build the desired part in layered form



3D Printing: Important Emerging Technology

Printing an actual usable wrench with moving parts

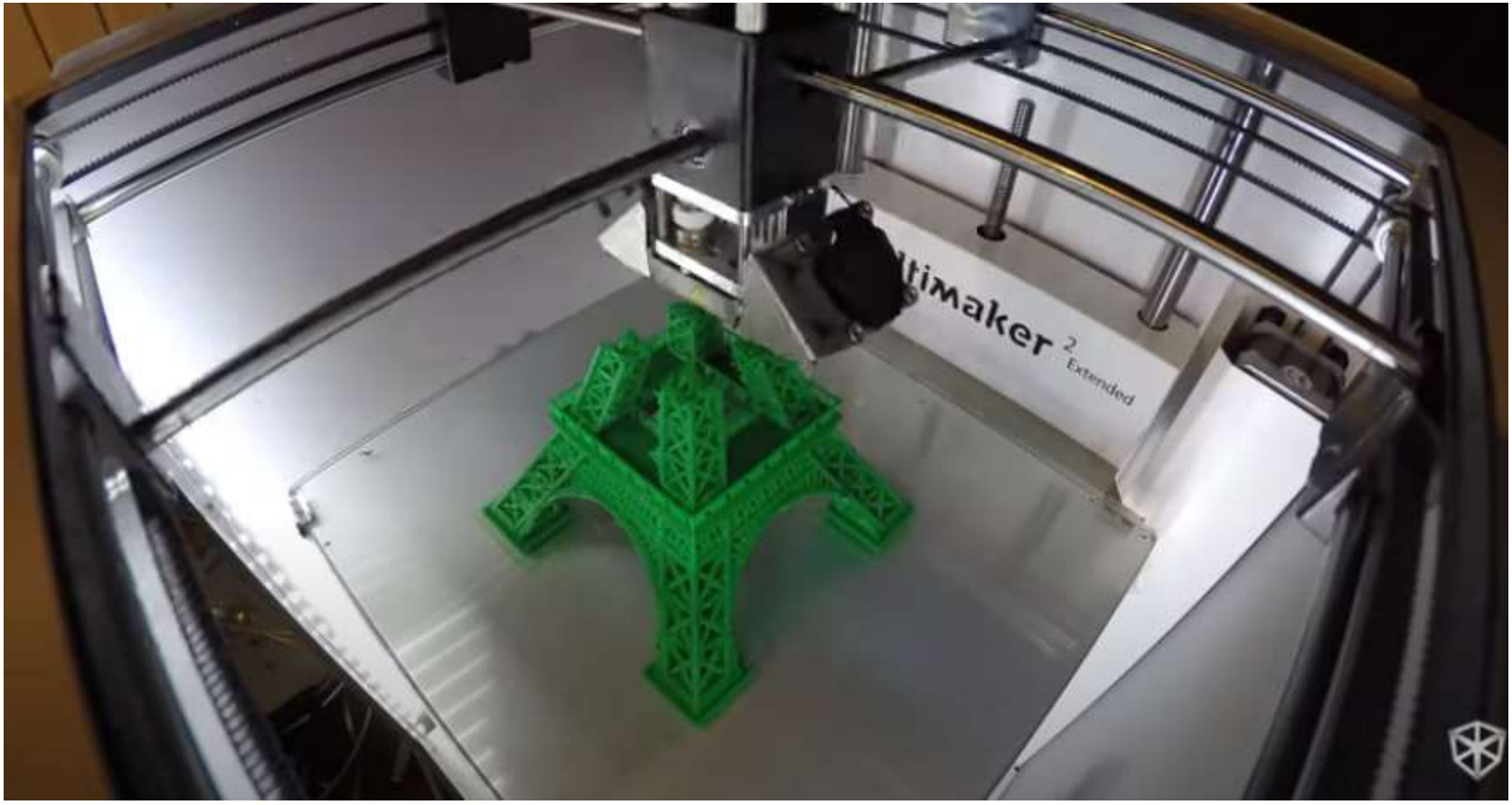
4-minute video: http://www.youtube.com/watch?v=qx5fDHqHVOE

Example 3D Printing Application

Airbus's Thor concept aircraft (2015, length 4m, weight 21 kg)
Built from sixty 3D-printed structural segments

The Eiffel Tower Built by a 3DPrinter

Printed on ColorFabb XT printer, with 0.1 mm layers, in ~ 20 hours
Time-lapse video: https://www.youtube.com/watch?v=FqQAjkZOBeY



3D Pen: For Playful Experimentation

Pen with rapidly cooling molten plastic "ink" for creating wireframes
2-minute video: http://www.youtube.com/watch?v=6r5q9T_7u8A

Questions?

To dig deeper, see:

L. Olsen, F. F. Samavati, M. C. Sousa, and J. A. Jorge, "Sketch-Based Modeling: A Survey," *Computers & Graphics*, Vol. 33, No. 1, pp. 85-103, February 2009.

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