Computer Graphics

Rynson W.H. Lau

Key Topics

- Computer Graphics applications
- Image synthesis: modeling and rendering
- Block diagram of graphics cards
- Computer animation

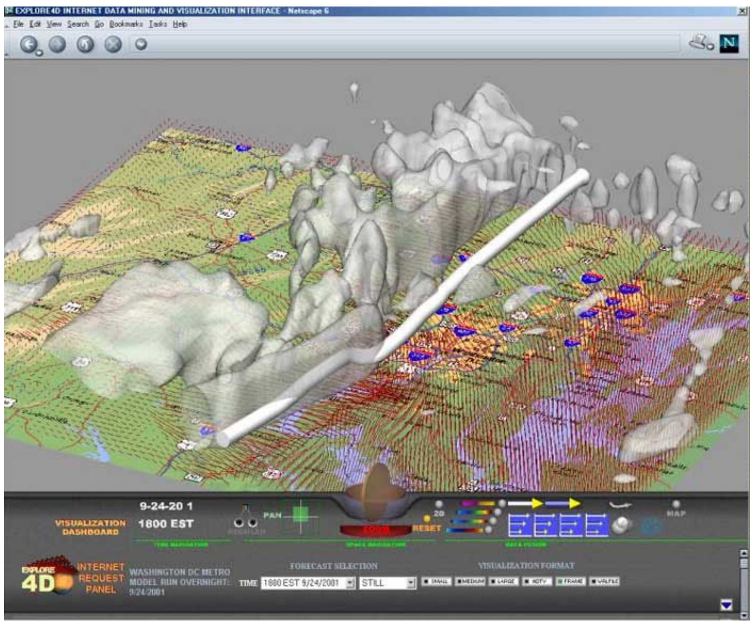
Applications of Computer Graphics

Computer graphics involves techniques for synthesizing realistic images and the applications of these techniques in our daily life.

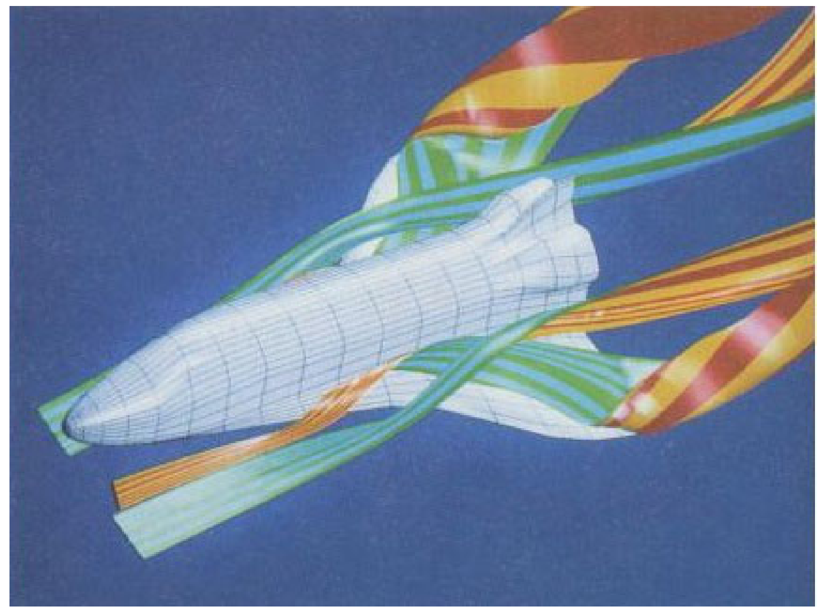
It has become very popular in recent years due to its success in many useful applications, in particular in computer games.

Other useful applications include…

- ***Visualization:*** display of complex phenomena or multi-dimensional data, which may be too difficult for users to understand otherwise.



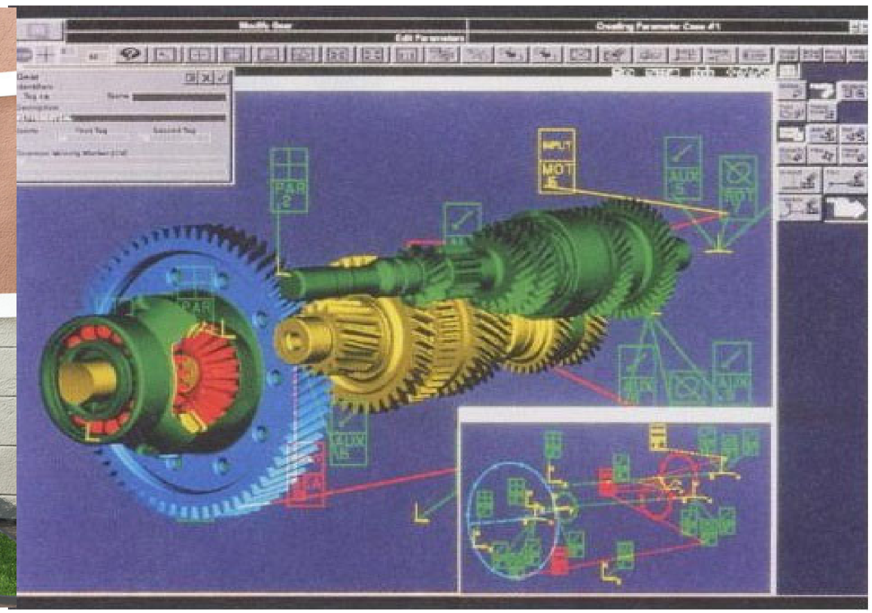
Numerical model of airflow inside a thunderstorm



Visualization of stream surfaces flowing past a space shuttle

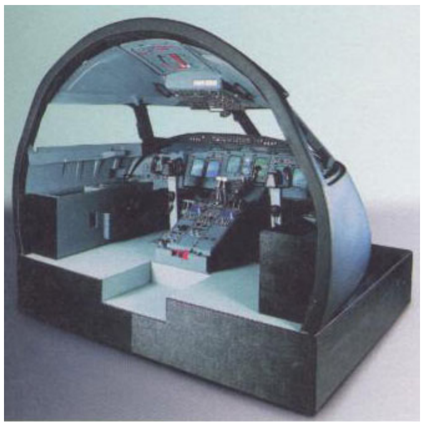
- ***Design:*** providing graphics tools to assist the design of objects, such as mechanical parts, or environments, such as buildings.

Architectural design



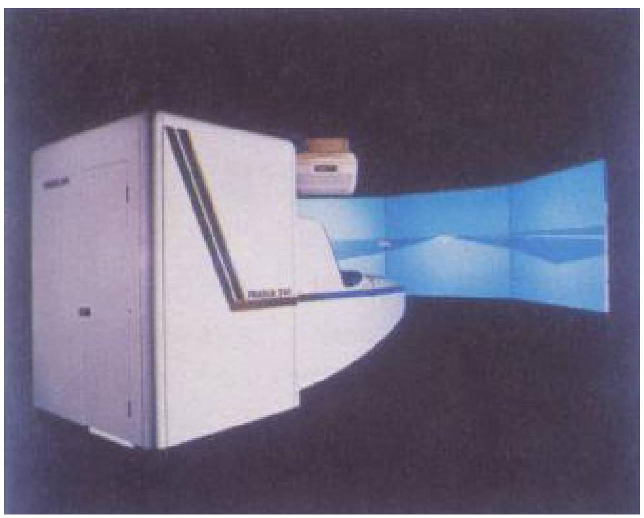
Machine design

- ***Simulation:*** simulating the behaviors of complex systems for training or investigation purposes.



Flight simulator

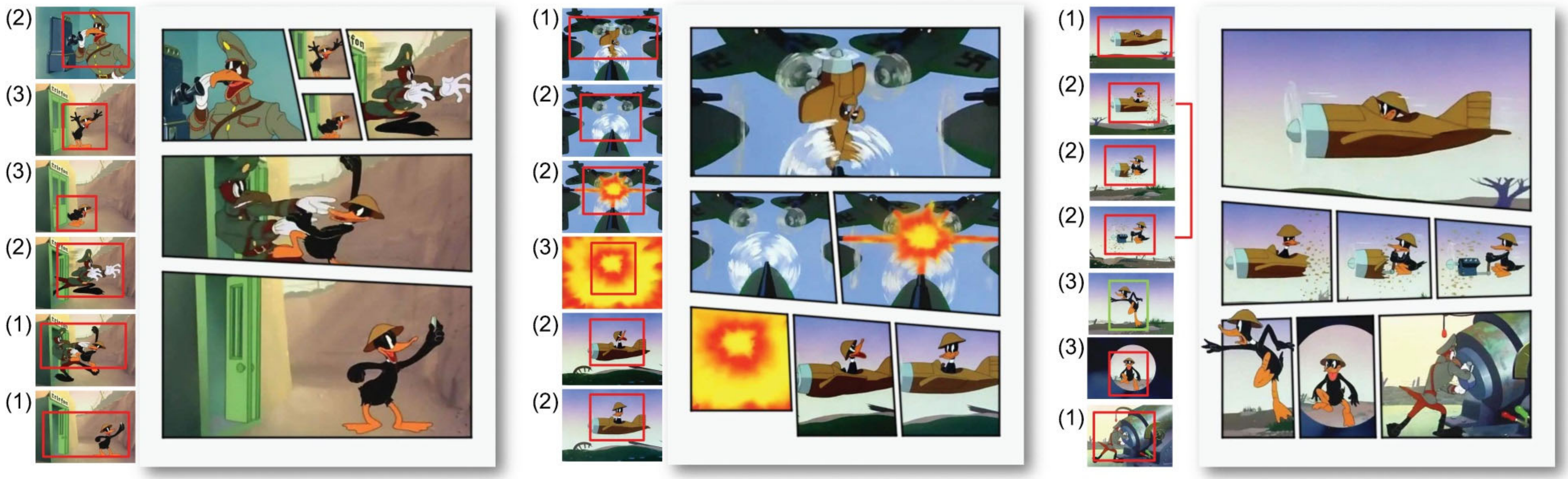
Automobile simulator



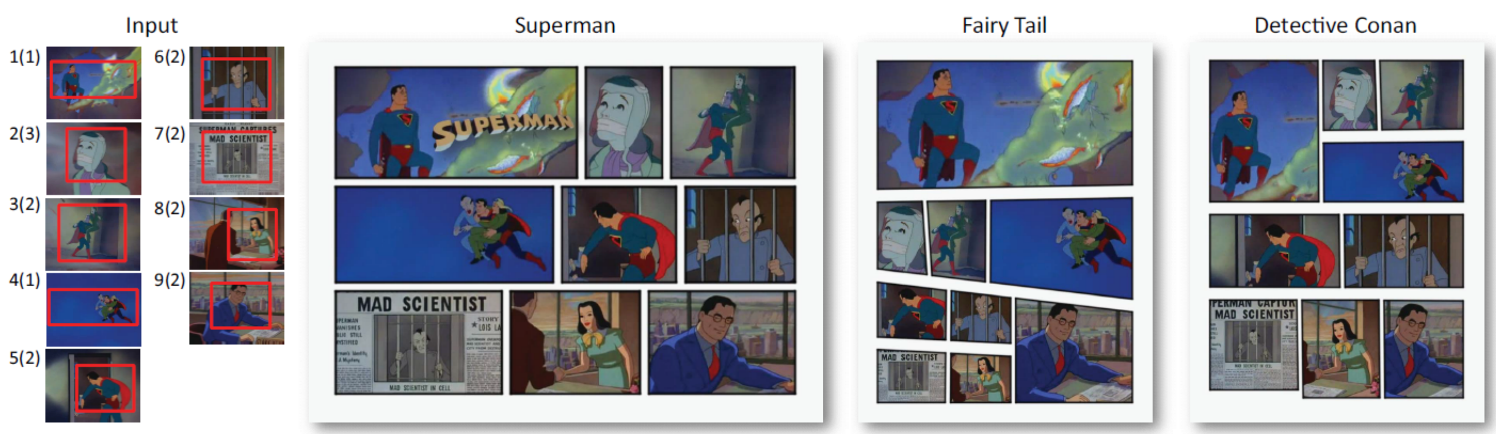
- ***Computer Animation and Movies:*** using computer graphics techniques to produce animations or movies.

- ***Computer Art:*** using computer graphics tools to assist artists in their designs.

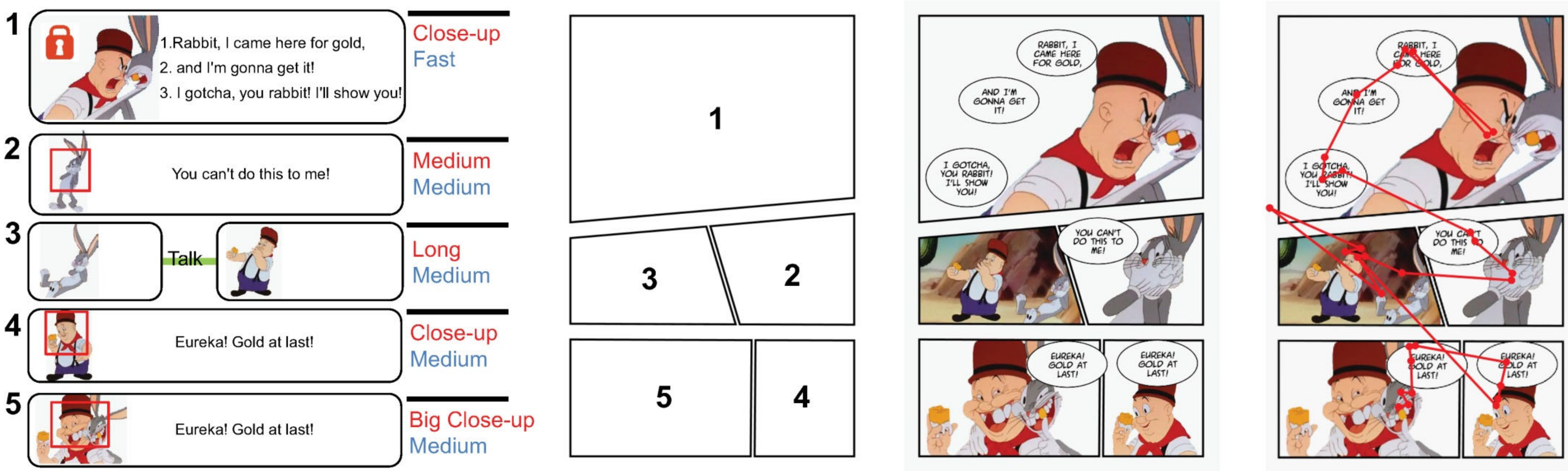
- ***2D Graphics Design:*** a tool to assist novices in laying out manga magazines: ***SIGGRAPH Asia 2012***: video



Automatic Manga Layout. Three layouts generated by our approach trained on “Fairy Tail”. The left side of each example displays the sequence of input artworks (“Daffy: The Commando”(1943) in the public domain), single-panel semantics, including importance-ranking values (within the parenthesis and region of interest (masked by rectangle), as well as optional inter-panel semantics that describe a group of consecutive semantically related panels (grouped by a red line in the rightmost example). The character masked by the green rectangle is chosen for a “fourth wall break” effect. The reading order of each layout is from left to right and then top to bottom.



➢ ***2D Graphics Design:*** a tool to assist novices in compositing manga contents:



(a) (b) (c) (d)

Attention-Directing Manga Element Composition. Given a storyboard comprising input subjects and dialogue for each panel ("The Wacky Wabbit" in the public domain), interaction type between any two subjects (green line connecting two subjects in panel 3), and shot type (red text) and motion state (blue text) of each panel (a), our approach automatically generates a layout of panels (b), and then produces a storytelling composition of subjects and speech balloons on the layout (c), which effectively directs the viewer attention through the page. Red rectangles on the subjects represent regions of interest, and a red lock icon in panel 1 indicates that the subject is fixed in place by the user. The recorded viewer's eye movements is plotted as a red path (d). The background image is added to provide necessary context. The reading order of manga is right to left, and top to bottom.

SIGGRAPH 2014: video

- ***2D Graphics Design :*** a tool for the web designers to develop attention guidance web designs:

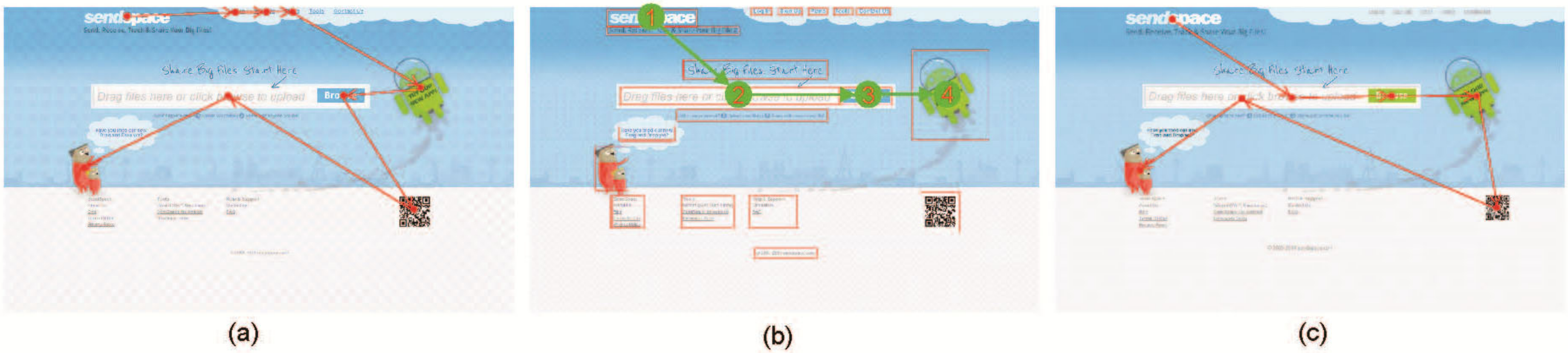
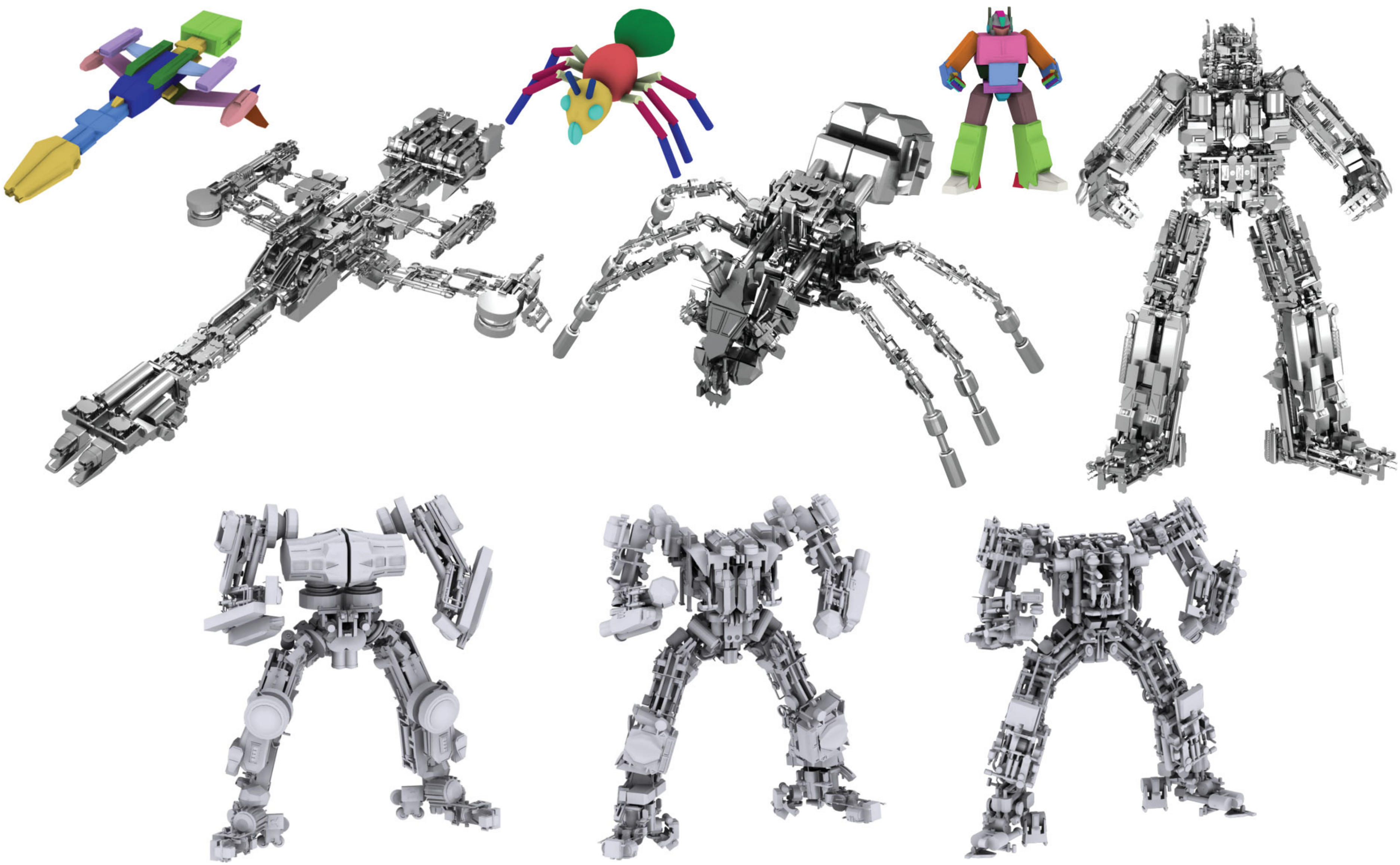


Figure 1: *Given an input web design in (a) and a designer-specified path (the green trajectory) over a subset of page components (red boxes) in (b), our method automatically generates a novel web design in (c) by modifying the properties of the components, such as position (e.g., the group of text links at the top), size (the QR Code at the bottom) and color (the button near the input field), so that the actual user attention paths match with the input path (i.e., the users' eye gazes when browsing the novel design should move across the subset of components successively along the input path). This results in a novel web design interaction that allows designers to easily create a visual flow to guide users (i.e., direct users' eyes to move along a specific path) through a web design. The red trajectories in (a) and (c) are the eye gaze paths of a test user on the input and novel designs.*

SIGGRAPH Asia 2016*:* video

- ***3D Design:*** a tool to construct 3D mechanical objects from a database of mechanical elements: ***TVCG 2014***: video



Computer Graphics Development

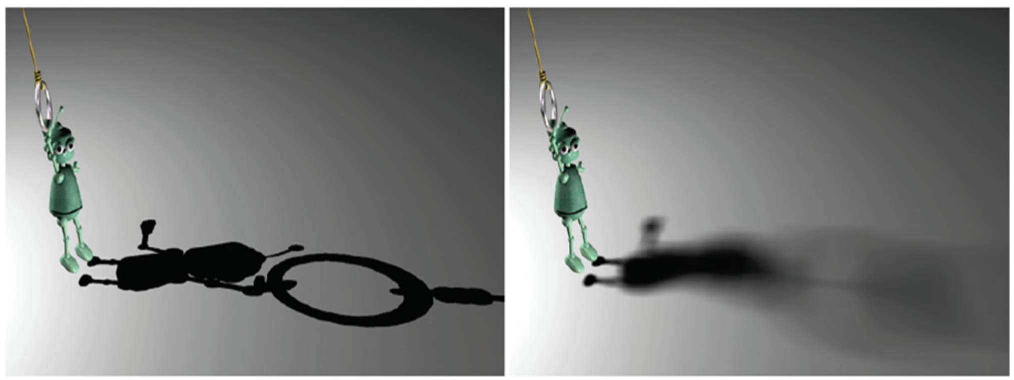
There are two main directions of development in computer graphics techniques:

- ***Realistic graphics***: It mainly focuses on developing methods to synthesize images as realistic as possible, such as generating shadows, adding haze and lighting.

- ***Real-time Graphics***: It focuses on the support of interactive applications, such as flight simulation and computer games. To achieve this, real-time graphics aims at producing each image within a specified amount of time.

  As an example, if we want to generate a video of 30 frames in each second, we will need to produce a single image within 0.033s. So, real-time graphics techniques try to produce an image as high quality as possible within 0.033s.

If the given time is not enough to render an image, one approach is to reduce the quality of the output image in order to save time.



Another approach is to reduce the number of frames per second. However, this may affect the viewers more.

original video at 24 frames/s   12 frames/s   2 frames/s

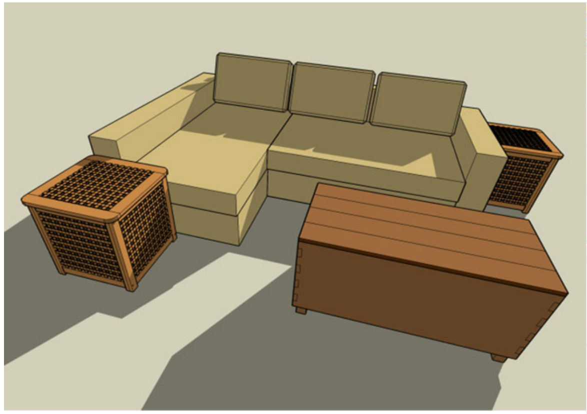
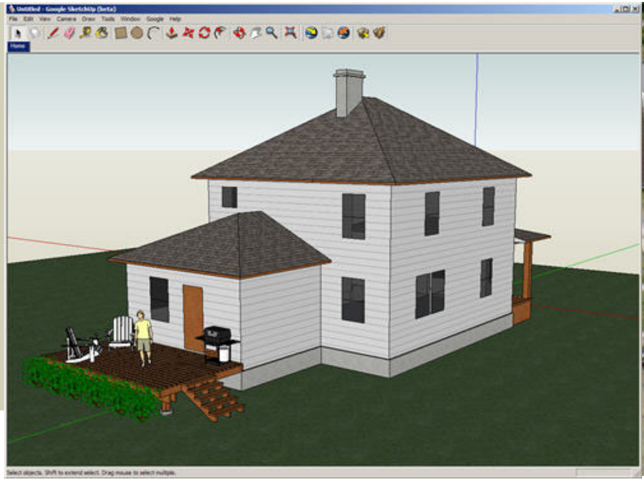
Image Synthesis

There are two main steps to produce computer images:

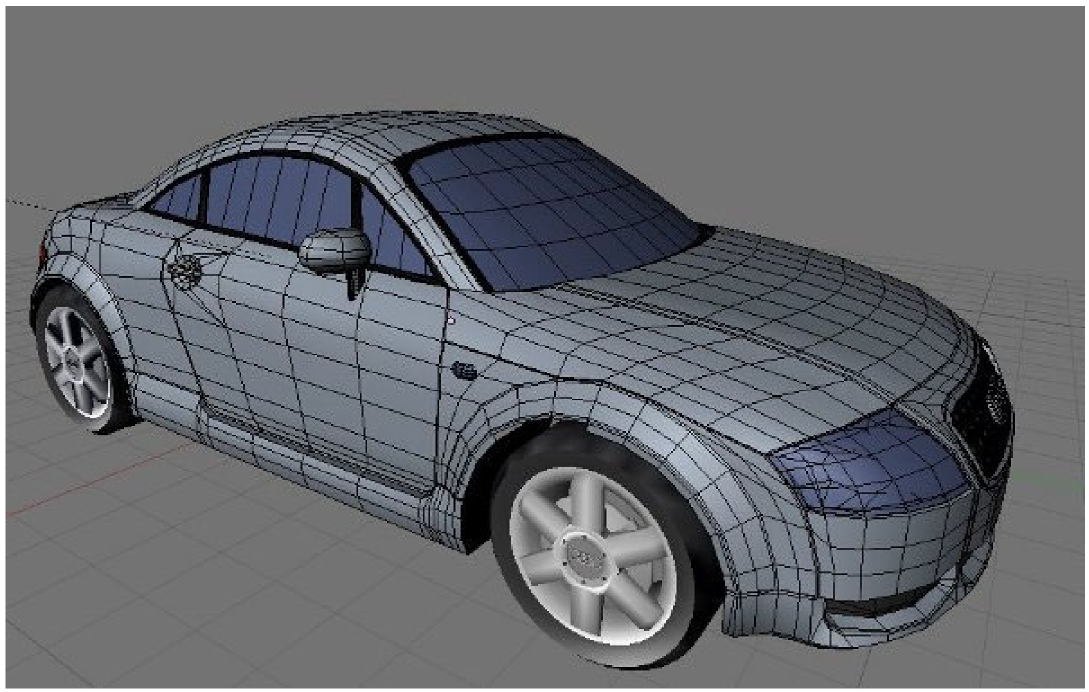
1. *Creating a 3D scene*
2. *Rendering the 3D scene*

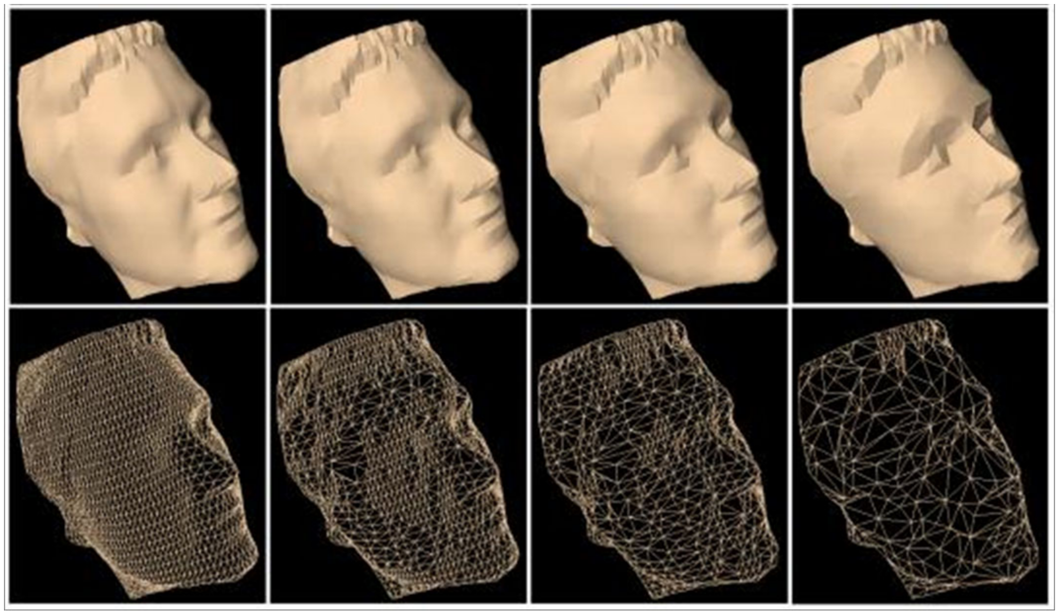
Image Synthesis
Creating the 3D Scene

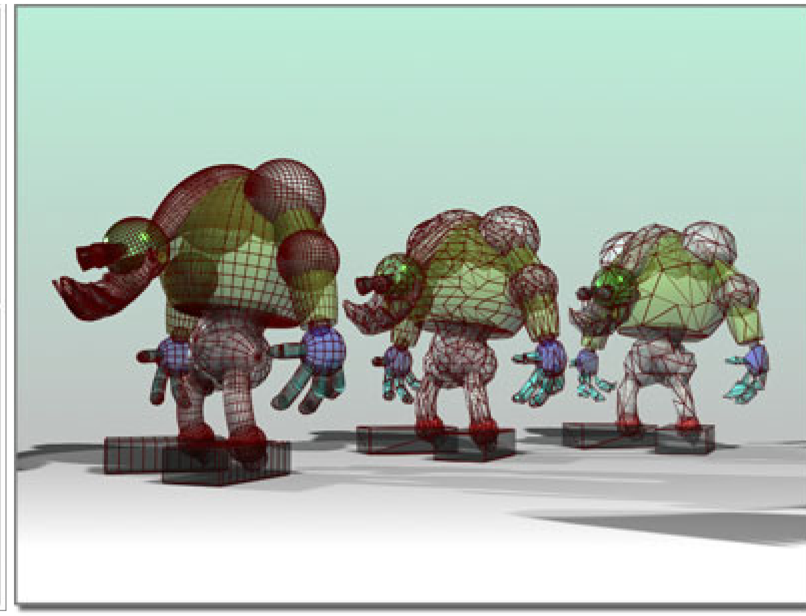
To create a 3D scene, we first need to construct each object in the 3D scene as a 3D geometry model. Many tools are available to do this, including *Maya*, *3ds Max* and *Google Sketchup*.

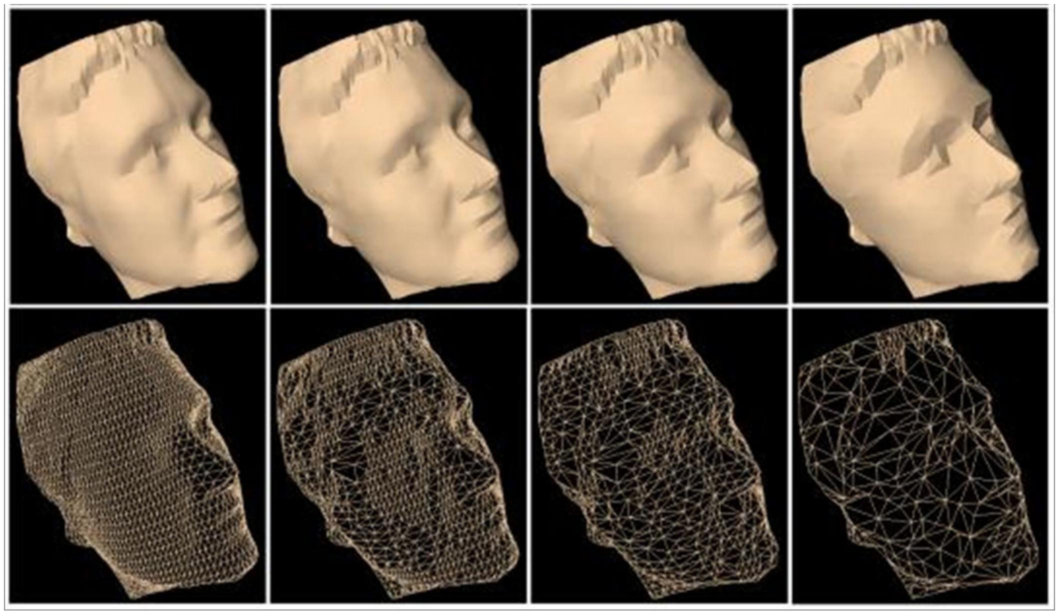

A geometry model is typically constructed by connecting many polygons together, forming the surface of the object.

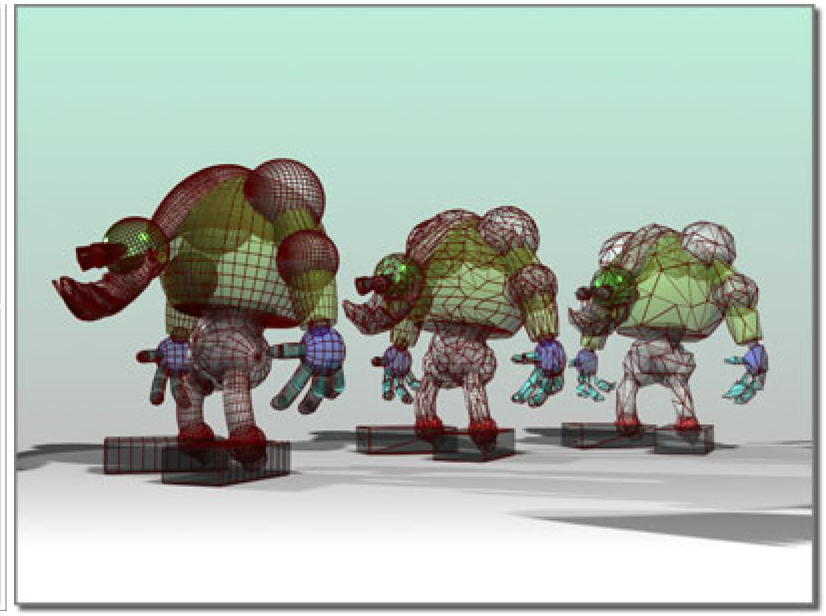






The question is: how many polygons are enough?

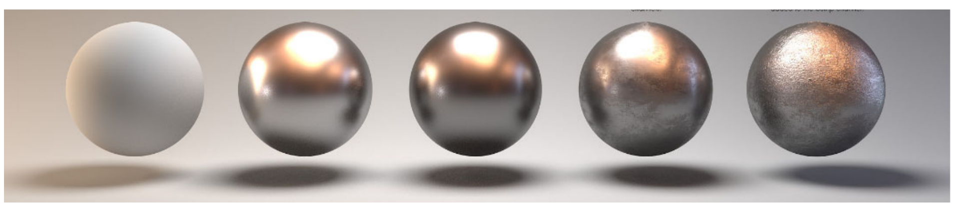


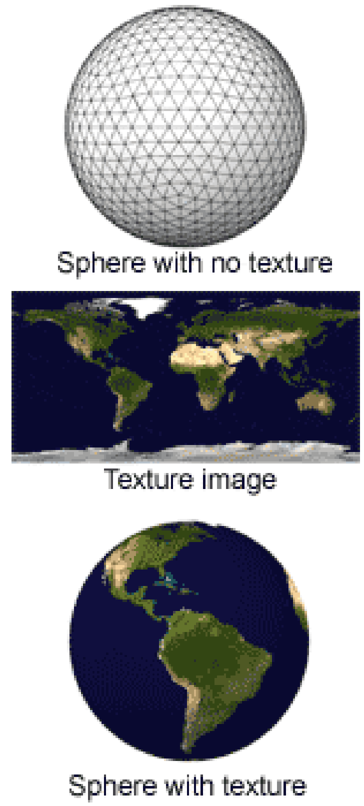


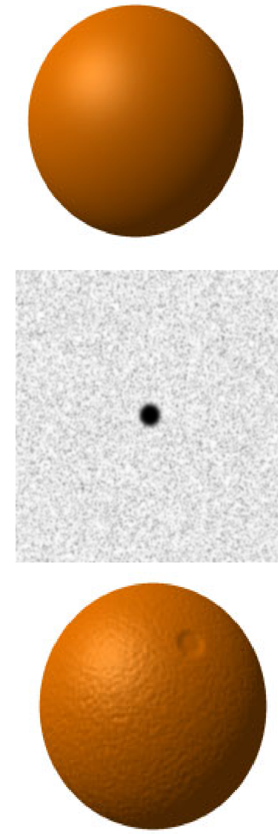
The question is: how many polygons are enough?

More polygons provide more details. However, more polygons take longer to render the object. So, … not too many and not too few.

Once we have created the 3D models. We may specify some properties for each 3D model, such as:







Material properties

texture map

height map

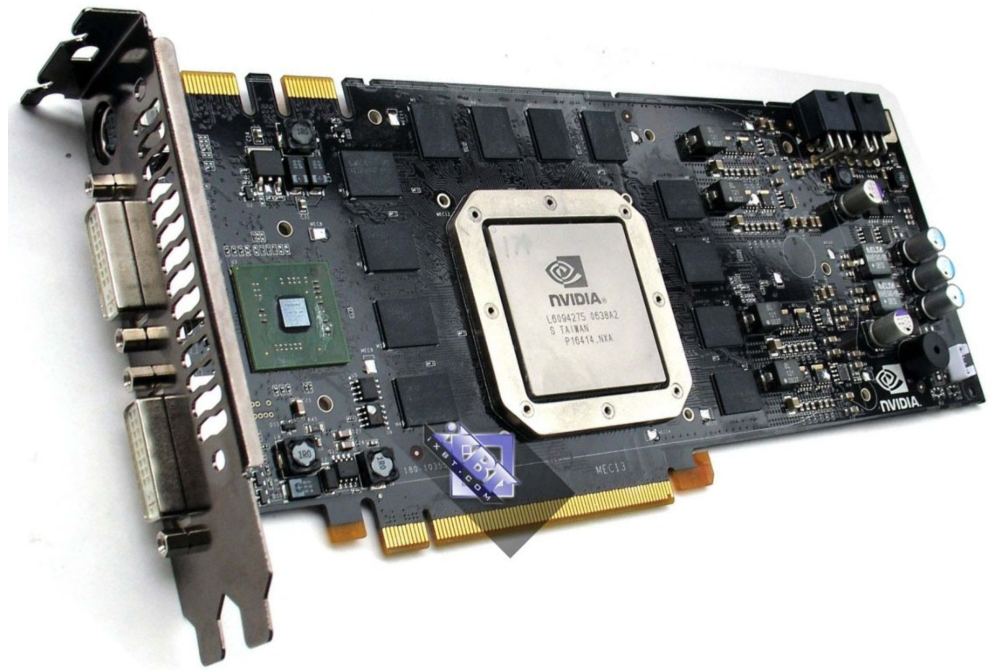
After we have prepared all objects, we may then put them together to form a 3D scene (or a 3D virtual environment).

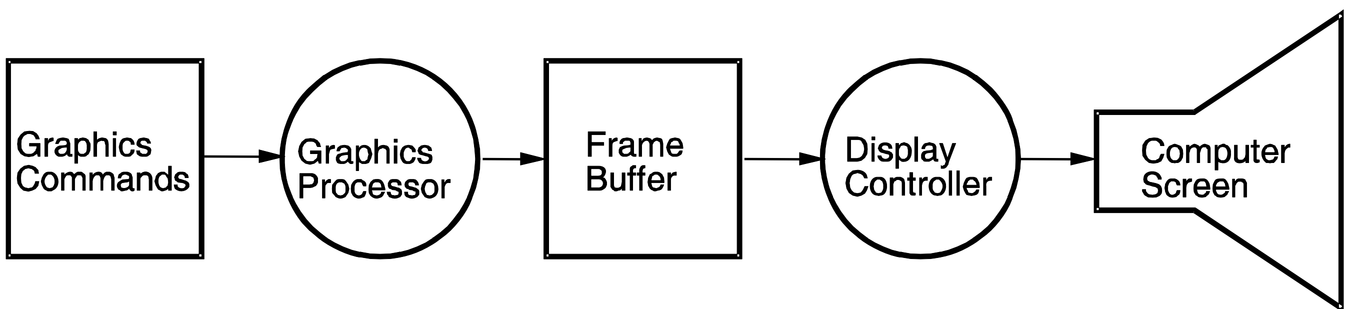
Image Synthesis
Rendering the 3D Scene

Once we have constructed the 3D scene, the user may specify a view point. The computer may then convert the 3D scene into an image from the given view point – rendering.

A graphics card helps perform this rendering function.

A typical graphics card and the corresponding block diagram are shown as follows:





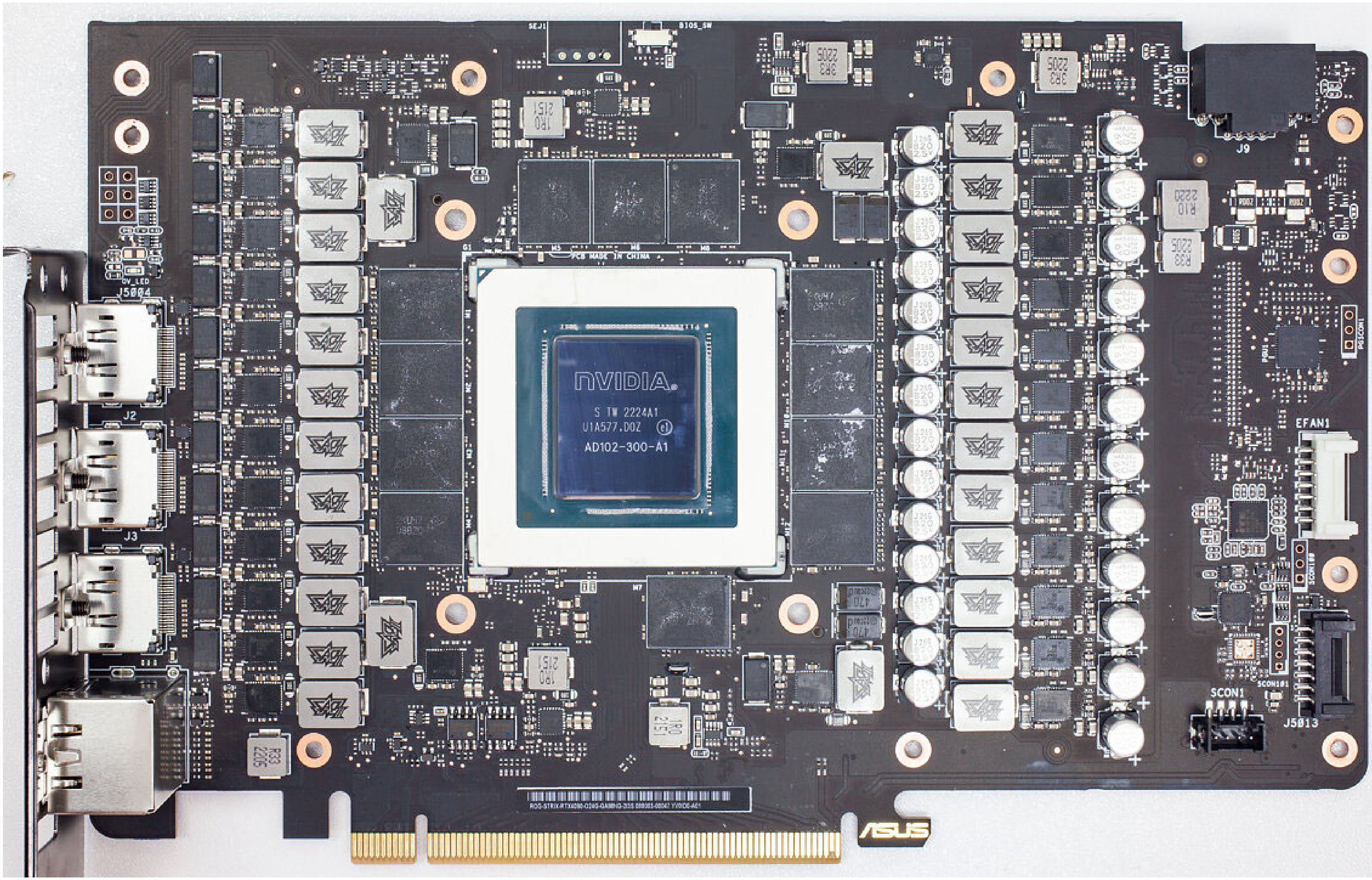
- Typically, the CPU runs the application, e.g., a computer game, and continuously generates graphics commands.
- These graphics commands, which are mostly related to drawing objects, are sent to the graphics card one by one.
- The graphics processor (also called GPU) draws each object polygon by polygon and sends the output to the frame buffer.
- The frame buffer is a local memory located in the graphics card. It is used to store the image being rendered.

- Once all objects in the scene are rendered, the image stored in the frame buffer represents the final image.
- The display controller will then generate suitable signals to read the frame buffer contents and to control the computer screen to display the rendered image.

One of the latest graphics cards: **NVIDIA Geforce RTX4090**

More info.: https://www.nvidia.com/en-us/geforce/graphics-cards/40-series/rtx-4090/

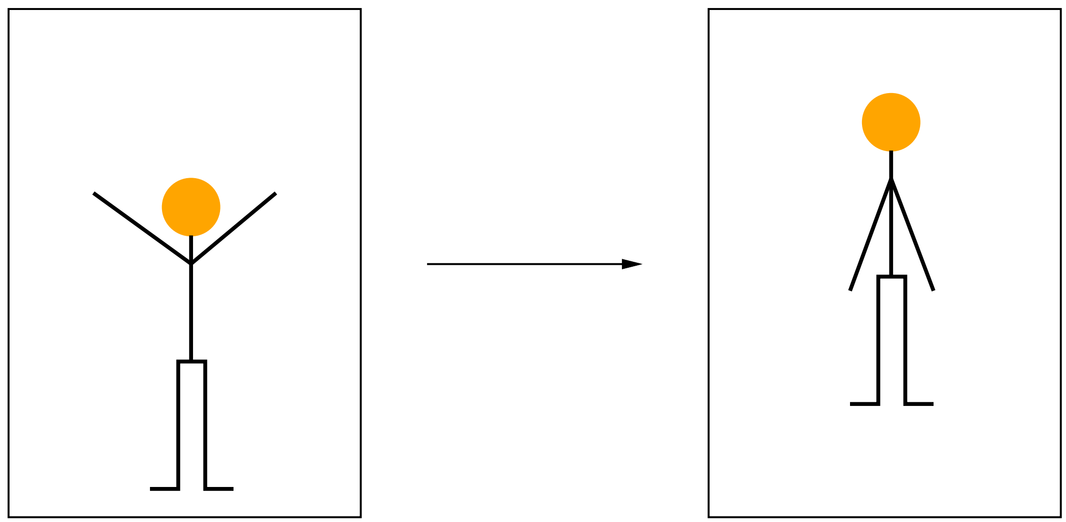
It contains 1 GPU, with 16,384 CUDA cores, and 24GB RAM. Power consumption: 450W.

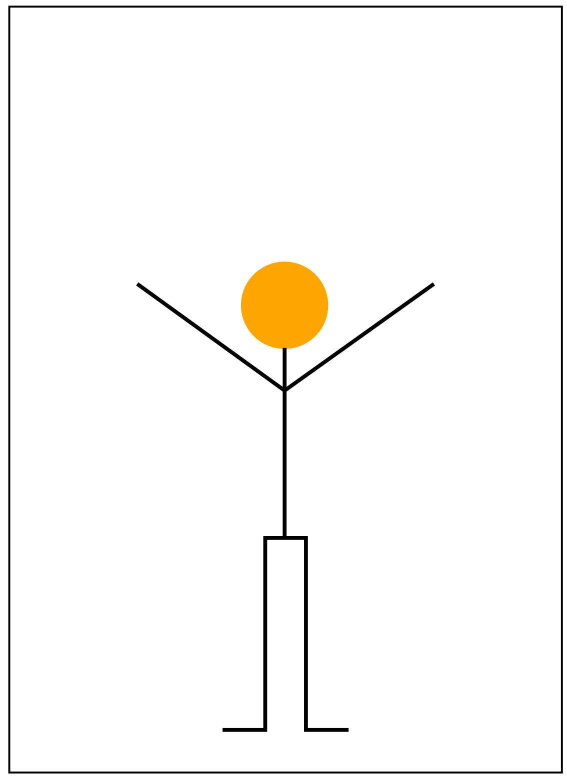


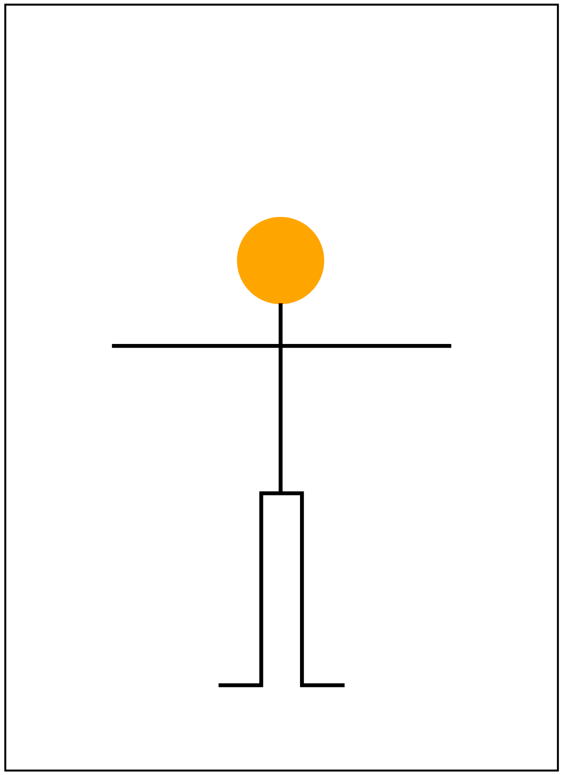
NVIDIA
S TW 2224A1
U1A577.D0Z
AD102-300-A1
PCB MADE IN CHINA
SEJ1
BIOS_SW
J5004
J2
J3
J9
EFAN1
SCON1
J5013
ASUS

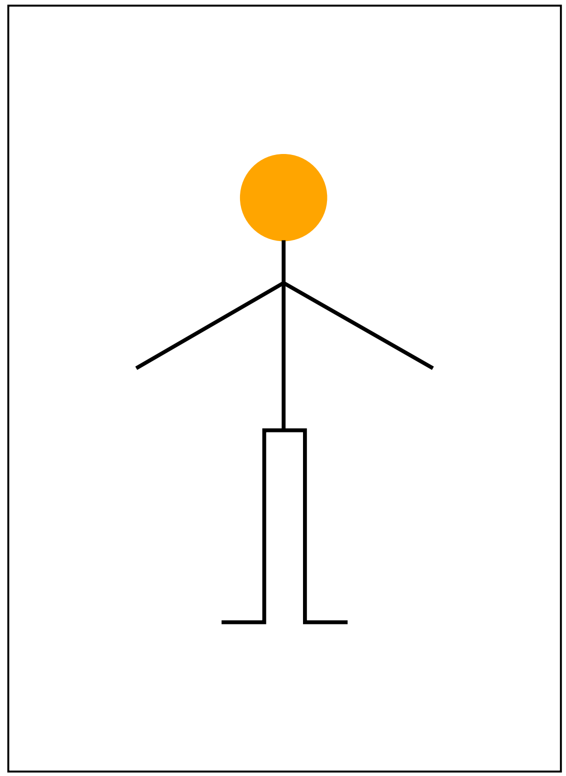
Computer Animation

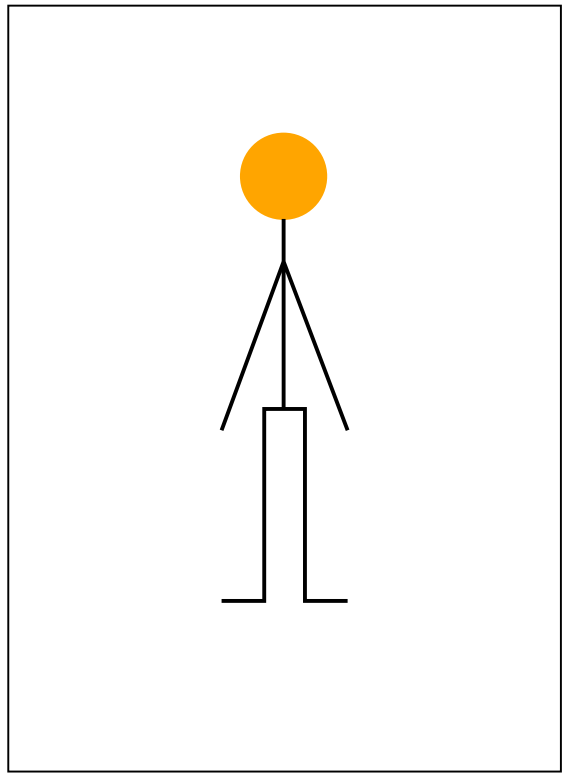
A popular animation technique is called ***key-frame animation***. The animator specifies the key positions of the object and the system interpolates them to generate the in-between positions.











See an animation demo at:
http://www.impressivewebs.com/demo-files/css3-animated-scene/

Animating a 3D object is more difficult.

A popular animation technique to move 3D objects around is to incorporate some intelligence or behavior into each object so that they can move around in the 3D scene:

- ***Artificial life***: to model the behavior of objects <video>
- ***Flock of birds***: to similate group behavior <video>

Fishes are simple objects. Animating a complex object, like human, is even more difficult. A technique called ***Inverse Kinematics***, is developed for animating humans.

Given the position and the motion of the end point of a limb, inverse kinematics applies kinematic equations to determine the positions of the other joints.

For example, the animator may only need to specify the position of the hand and the system can derive the joint positions of the arm. <video>

Since simulating real object motion realistically is very difficult, ***motion capture*** techniques become popular in recent years.

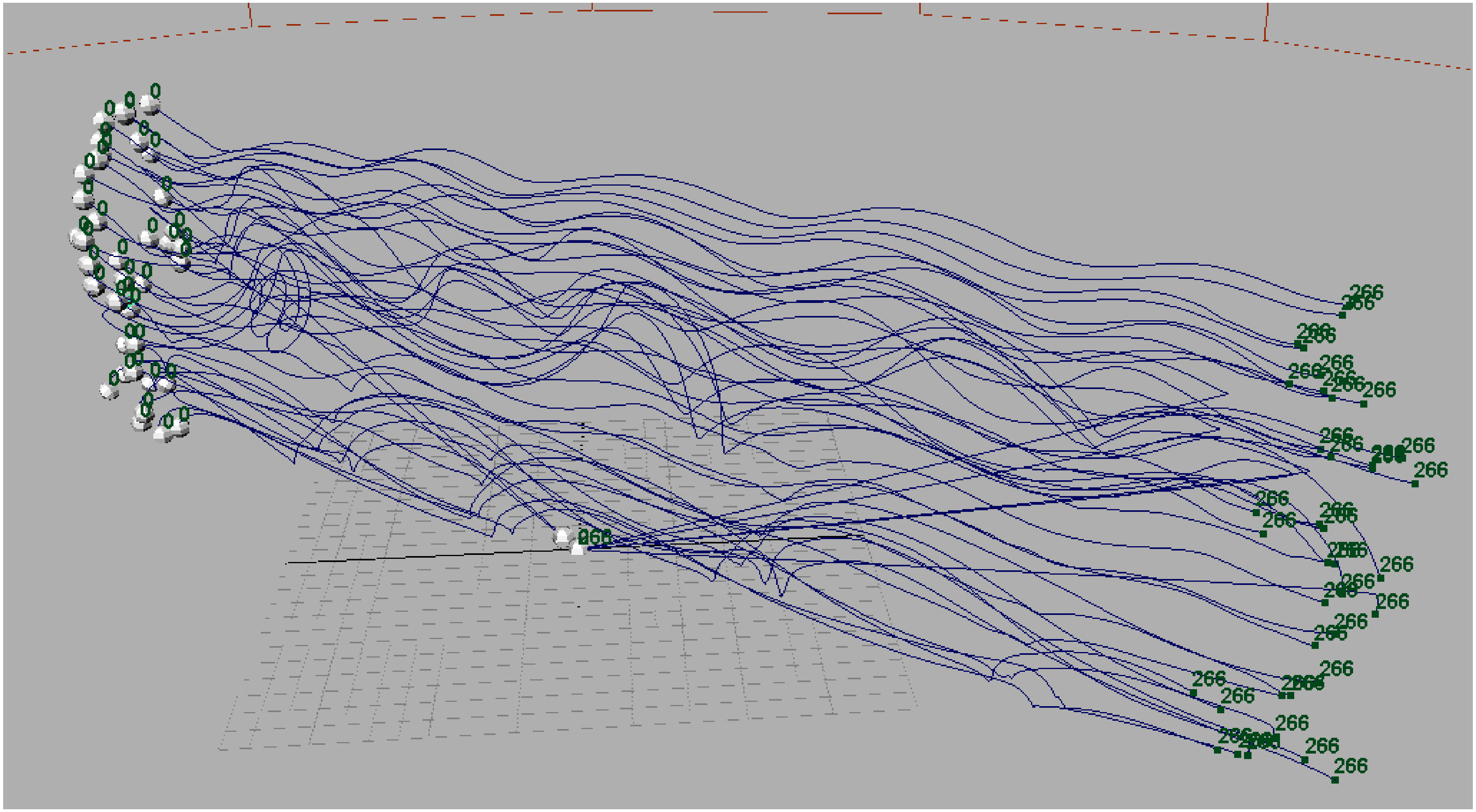
The idea of motion capture is to use some devices to capture the real motion of an object (in particular human). The captured motion can then be used to guide the motion of a virtual object.

For example, we may want to model a virtual object to play baseball. A popular device to capture a person's motion is the ***optical motion capture system***, which is based on projecting infra-red lights on the person and then capturing the reflections using some high resolution cameras:

- 3D reflectors are attached to different body parts of a baseball player to capture his movement. <video>
- The captured motion information <video> can then be used to guide the movement of the virtual baseball player. <video>

By exaggerating the captured information, it is even possible to produce some interesting effects. <video>

Motion capture data:



Human facial expression is equally difficult to simulate. To capture facial expression, a popular method is to put markers on the face and then use cameras to capture the movements of the markers over time.

Motion and facial capture systems can be very expensive.

The Microsoft Kinect may address these problems:

- Motion capture: http://www.youtube.com/watch?v=Ip17d9jfoDM
- Facial capture:

http://www.youtube.com/watch?v=Iet0xvjdCus&list=PL794650B0DFBDD07F&index=3