COMP220: Graphics & Simulation

1: Introduction to Graphics and Simulation

Learning outcomes

By the end of this week, you will be able to:

- **Understand** the context of computer graphics and simulation in games.
- **Recall** some of the main areas of interest in graphics and simulation.

Computer graphics

What is computer graphics?

- The process of representing 3D virtual objects on a screen.
- "The creation of, manipulation of, analysis of, and interaction with pictorial representations of objects and data using computers." – *Dictionary of Computing*
- Trying to make it look as convincing and/or interesting as possible:
  - Shape representation - **modelling**
  - How light interacts with the surface - **shading**
    - (Photo)realistic vs. stylised, e.g. cel shading
  - How light travels around the scene - **rendering**
  - Enhancing the image - **post processing**

Modelling

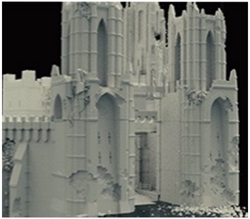


Image courtesy of Framestore

- Defines the outline/shape of an object, usually by identifying points or **vertices** on its surface
- Vertices can be generated by an artist using a 3D modelling package, or may be generated procedurally
- More vertices => more accurate shape => more data and longer processing times
- Algorithms can be used to reduce model complexity without compromising appearance

Shading and rendering

Image courtesy of Framestore

- Models are given **textures** and other surface properties as **materials**
- Use equations from physics to define how light behaves and interacts with materials
- A variety of simplifications exist that approximate (some of) the full equation, e.g. Phong shading
- Generate an image using **projection**

Post processing

Image courtesy of Framestore

- Used to create "in-camera" effects, e.g. motion blur, bloom
- Applied to the 2D projected image of the scene
- Can use the **frame buffer** to implement fast techniques for lighting effects, e.g. shadows, reflection etc.

Simulation

What is simulation?

- Replicating (physical) behaviour using equations (e.g. Newton's Laws of Motion).
- Different kinds of objects behave differently:
  - Motion through space resulting from external forces - **particle simulation**
  - Changes in orientation resulting from external forces - **rigid body dynamics**
  - Changes in shape resulting from external *and internal* forces - **soft-body deformation**
    - Some types of object have specific techniques, e.g. **hair, cloth** and **fluid**
  - Automating aspects of manual animation processes - e.g. **inverse kinematics (IK)**

Particle simulation

Image courtesy of Framestore

- Used to predict the behaviour of dimensionless **point mass** objects
- Computed one frame at a time, to account for **collisions**
- Can be used for fluid-like effects such as smoke

Rigid body dynamics

Image courtesy of Framestore

- Used to predict the behaviour of **non-deformable** objects
- Global motion is computed as for particles...
- ... combined with local motion (rotation) about the object's centre of mass
- Commonly used for destruction sequences

Soft body dynamics

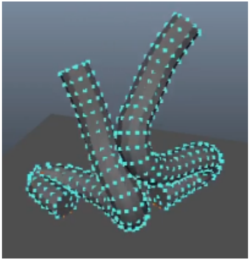
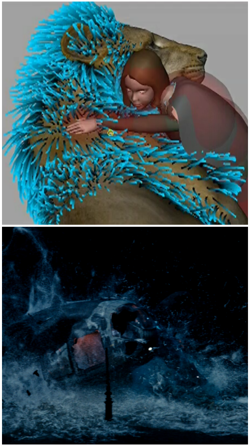


Image courtesy of Framestore

- Used to predict the behaviour of **deformable** objects
- Requires knowledge of the interior of an object (e.g. FEM): computationally very expensive
- Often approximated using **constrained rigid bodies** and other techniques

Other types of dynamic simulation



Images courtesy of Framestore

- Objects such as **hair, cloth** and **liquids** behave slightly differently
- These have their own equations and techniques...
- Beyond the scope of this module!

Rigging and animation

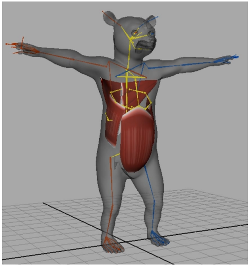


Image courtesy of Framestore

- Key characters (and objects) are hand-animated by artists using a **skeleton rig**
- Positioning each joint would be a laborious process...
- Techniques such as Inverse Kinematics (IK) have been developed to automate certain aspects.

Context and applications

Why are graphics and simulation important?

- More than 50% of the cortex, the surface of the brain, is devoted to processing visual information (David R. Williams, William G. Allyn Professor of Medical Optics at the University of Rochester; reference here).
- Most computer output appears on the screen.
- Enables intuitive observation of data, representing:
  - locations, orientations and dimensions of objects in space
  - statistical or experimental results

Applications

- Entertainment: games, virtual reality, films/TV
- Architecture and CAD
- Engineering
- Science and medicine

Challenges

- Accuracy vs. speed: complex calculations take time...
- Solution: use approximations, considering:
  - Which objects do we really need to see?
  - How much detail do we need to see them in?
  - What can be sacrificed without compromising the end result (too much)?
- Optimisations are possible at each stage of the graphics pipeline
- Different applications require different balances of trade-offs; in games, speed is paramount (but detail is desirable!)

Next steps

Now you have a general idea of what graphics and simulation is about, and the factors to bear in mind whilst implementing the techniques,

- **Review** content from COMP270 on the graphics pipeline.
- **Research** the main topics within graphics and simulation to decide which areas you'd like to focus on for your artefact.