Chapter I
Introduction

3D Computer Graphics

- 3D computer graphics takes as input 3D representations of objects and produces images.
- An illusion of movement is made on the screen by quickly displaying a sequence of changing images, called *frames*.
- Depending on how fast the frames are generated, computer graphics is classified into two fields.
    - Real-time or interactive graphics
        - More than 30 frames per second (fps)
        - Games, virtual reality, and interactive user interfaces (UIs)
    - Non-real-time graphics
        - Seconds, minutes, or even hours for a single frame
        - Visual effects in films (ILM) and animation (Pixar)
- The algorithms and techniques adopted in real-time graphics are quite different from those in non-real-time graphics.
- This class focuses on real-time graphics and presents its essential components.

Computer Graphics Production

- The flow of computer graphics production is often described as five steps:

modeling → rigging → animation → rendering → post-processing

- Graphic artists and programmers are the key players.

  - The artists create graphics assets, and are in charge of modeling, rigging, and 'half' of animation.

  - The programmers are in charge of the other half of animation, rendering, and post-processing.

  - Roughly speaking, the animation step is partitioned into off-line tasks and run-time tasks, which are handled by artists and programmers, respectively.

Modeling

- A *model* is referred to as a computer representation of an object, and *modeling* is the process of creating the components of the virtual environment.

- The most popular modeling method in games is using *polygons*, and the model is called *polygon meshes*. Shown below are the *triangle mesh* examples.
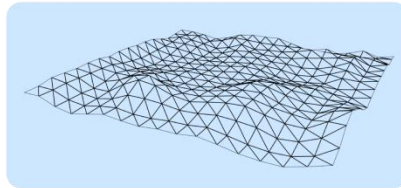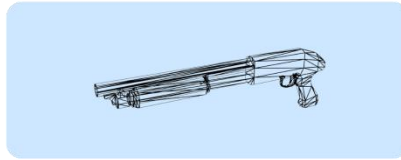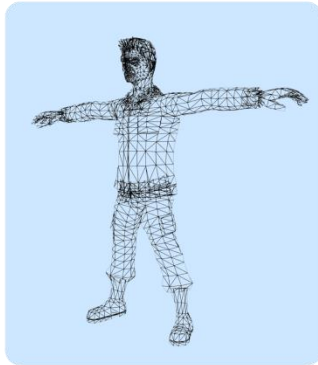
- The scope of modeling is not limited to constructing 3D models, but includes creating *textures* that are added to the 3D models to increase their realism.
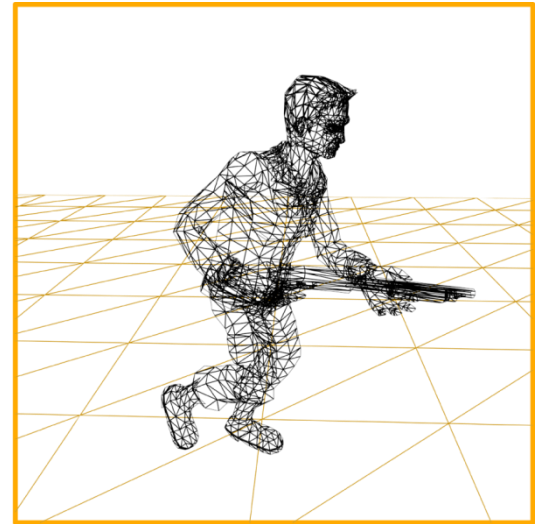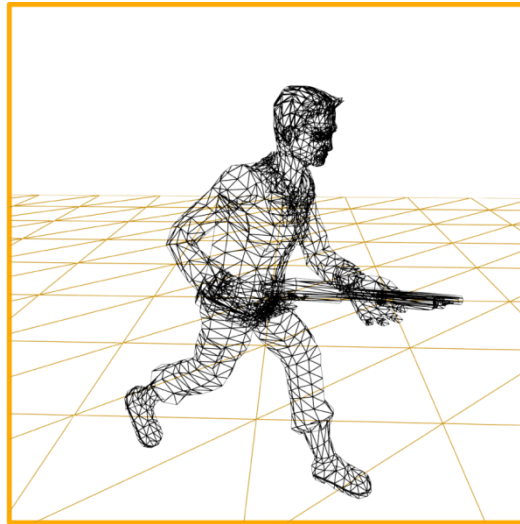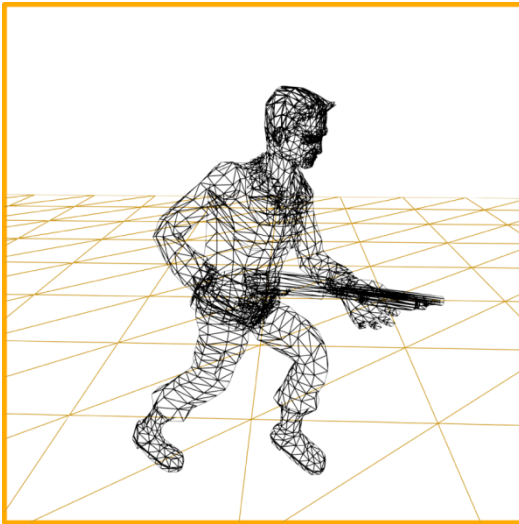

texture image

Rigging and Animation

- Consider a soldier model. Unlike static objects such as the terrain, it should be able to walk, run, and crawl.


- Dedicated programs such as 3ds Max and 3ds Maya are popularly used for modeling and off-line animation.

Rigging and Animation (cont'd)

- For the animation purpose, we usually specify the *skeleton* or *rig* of the soldier and define how the skeletal motion deforms the soldier's polygon mesh. This process is referred to as *rigging*.

- Then, for example, the polygons around the arm will move if the arm-bone moves.

skeleton   skeleton embedded into the mesh   animated mesh
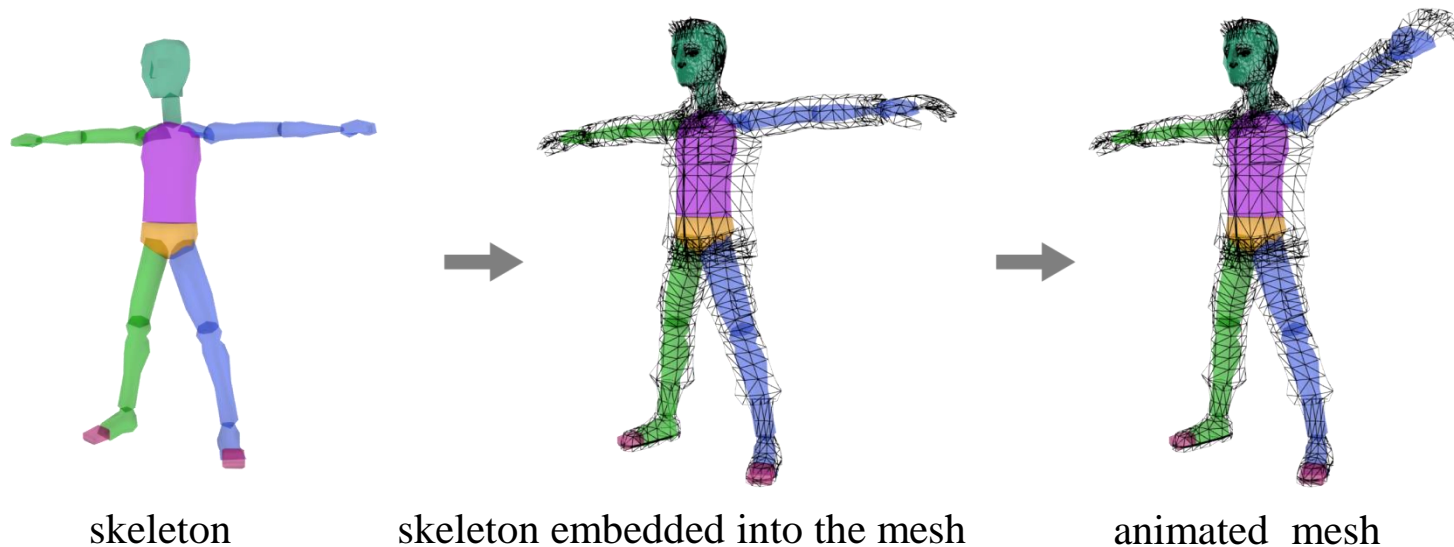
- This figure illustrates the bones as if they were surfaces, but the bones do not have explicit geometric representations. They are just conceptual entities. This issue will be presented later in detail.

Rendering

- For each animated frame, the scene needs to be updated.
  - The objects involved in run-time dynamics are updated. It's *physics-based simulation*.
  - For the object to be animated, its shape and pose are determined.
  - Lighting conditions and viewer positions can be changed.
- *Rendering* is the process of generating a 2D image (frame) from a 3D scene.

Post-processing

- This step may generate many effects including motion blur, depth-of-field (DOF), HDRI (high dynamic range imaging), etc.

  - When a camera captures a scene, the resulting image represents the scene over a period of time, which is short though. Consequently, rapidly moving objects may result in motion blur.

  - DOF effect makes the objects out of the camera focus blurry.

  - HDRI effect mimics the range of intensity levels found in real-world scenes.

Introduction to Computer Graphics with OpenGL ES (J. Han)

Game Program Hierarchy

- Unlike modeling, rigging, and off-line animation conducted by artists, run-time animation, rendering, and post-processing are executed by a game program.

- In general, a game program is built upon a *game engine* which provides a suite of reusable software components (for rendering, physics simulation, sound, artificial intelligence, etc.) and development tools.

- A game engine is built upon graphics APIs such as OpenGL ES.

- Graphics APIs provide essential graphics functions that are implemented in a processor specialized for graphics, named GPU. The APIs translate the application's graphics commands to instructions that can be executed by the GPU.

game program (app)
game engine
graphics API (OpenGL ES)
GPU
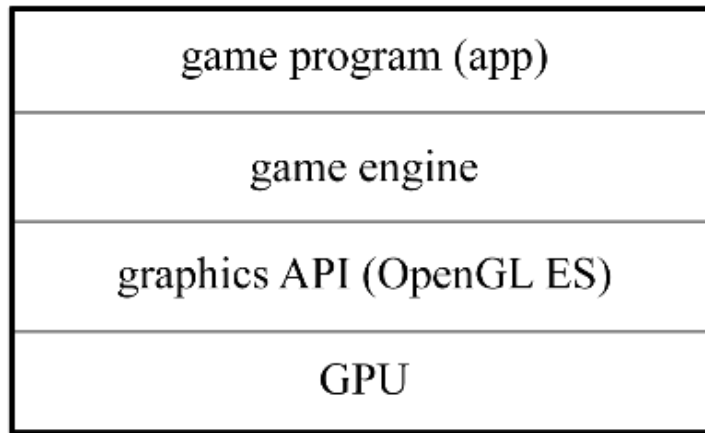
Graphics API

- Graphics APIs

  - Direct3D is part of Microsoft's DirectX API, and is available only for Microsoft platforms.

  - OpenGL is a cross-platform standard API managed by a non-profit consortium, the Khronos Group.

  - OpenGL ES (OpenGL for Embedded Systems) is a 3D API for handheld and embedded devices and it consists of subsets of OpenGL.

Game Engine

- A four-year-old state-of-the-art in *real-time rendering* ☺

Virtual Reality

- The term, *Virtual Reality* (VR), was initially coined at 1989.
  - HMD (Head-Mounted Display)
  - CAVE (Cave Automatic Virtual Environment) projects images on the walls and floor of a room-sized cube.

HMD

CAVE

HMD for VR

- HMD is a headset that displays stereo images to provide its wearer with an *immersive* experience.

- A scene is rendered into two warped side-by-side views. It's the stereoscopic image that creates the illusion of depth by means of stereopsis for binocular vision.

- It should include *head-tracker*.