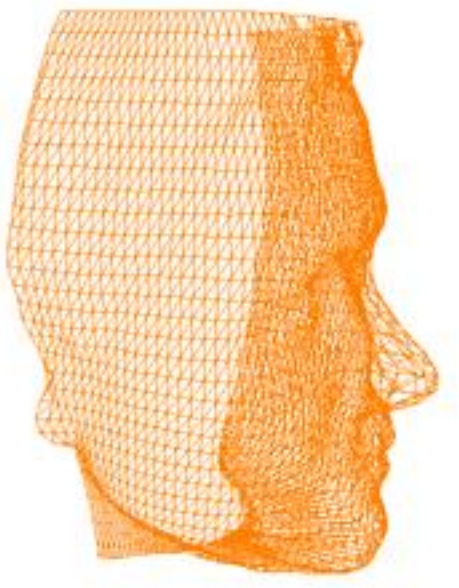
COSC422 Advanced Computer Graphics



0 Course Overview

Semester 2
2021

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University of Canterbury, New Zealand.

Introduction

COSC422 covers a range of topics that find applications in the following areas:

- Shader based real-time rendering
- Mesh processing algorithms
- Scene graphs and character animation

Tentative List of Topics

Week 1: Introduction to OpenGL-4 shader stages

Week 2: Tessellation and Geometry shaders

Week 3: Sprites, Pencil Shading, Transformation Feedback (XFB)

Week 4: Image Based Rendering (RTT, Impostors, Shadow map)

Week 5: Mesh Processing: Data Structures, Mesh Simplification

Week 6: Mesh Subdivision Algorithms

Week 7: Mesh Parameterization, Morphing

Week 8: Quaternions, Spherical Linear Interpolation (SLERP)

Week 9: Scene Graphs, MOCAP, Skeletal Animation

Week 10: Vertex Skinning, Character Animation

Week 11: Forward and Inverse Kinematics

Week 12: Summary

Learning Outcomes

After completing the course, students will be able to

- Understand, implement and analyze important real-time rendering algorithms used in computer graphics
- Explain the computational steps in the OpenGL-4 pipeline
- Develop shader based graphics applications
- Apply mesh data structures for processing 3D meshes
- Develop algorithms for mesh simplification and mesh subdivision
- Design and implement skeletal animation methods for character animation
- Design character animation sequences using motion capture data and quaternion transformations

Prerequisites

- Computer Graphics (**COSC363** or equivalent)
  - **Introductory concepts** in computer graphics:
    - 3D Modelling: Polygonal models, Surfaces of revolution etc.
    - Illumination Model (Phong-Blinn equations)
    - 3D-Transformations and Projections
    - Texture Mapping.
  - The **OpenGL-4 API**, including the shader stages:
    - Buffer Objects
    - Vertex and Fragment Shaders
    - Tessellation and Geometry Shaders
- C/C++ programming (**ENCE260** or equivalent)

Assessment Items

- Assignments: 60%
  - Assignment 1 (20%) Due: 13 Aug 2021

    Topic: Terrain Rendering
  - Assignment 2 (20%) Due: 24 Sep 2021

    Topic: Mesh Processing
  - Assignment 3 (20%) Due: 20 Oct 2021

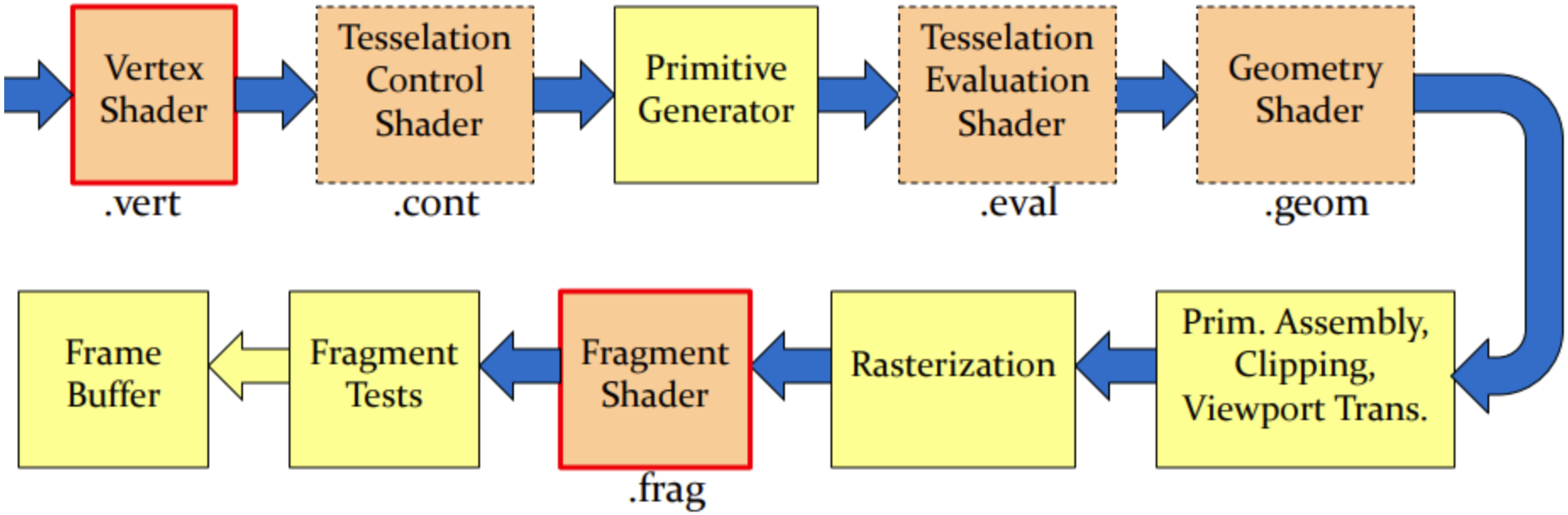
    Topic: Character Animation
- Final exam (2 hours, Closed book) : 40%

APIs/Libraries

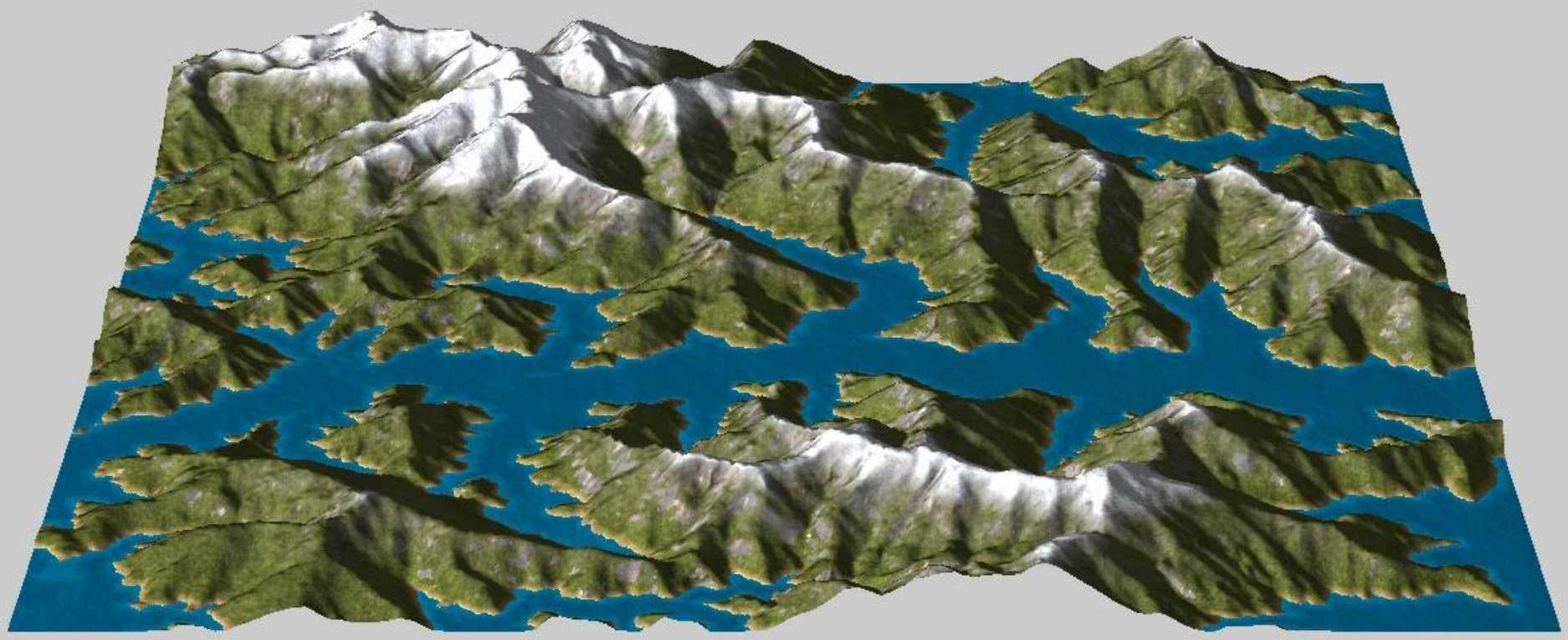
- OpenGL Mathematics (GLM)
  - https://glm.g-truc.net/0.9.9/index.html
  - GLM 0.9.9.7 (2020)
- Open Mesh Library
  - https://www.graphics.rwth-aachen.de/software/openmesh/
  - OpenMesh 8.1 (2020)
- Open Asset Import Library (Assimp)
  - https://www.assimp.org/
  - Assimp 5.0 (2019)
- Open Image Library (OpenIL/DevIL)
  - http://openil.sourceforge.net/

A Quick Tour

OpenGL-4 - Pipline

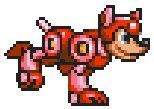


Terrain Programming



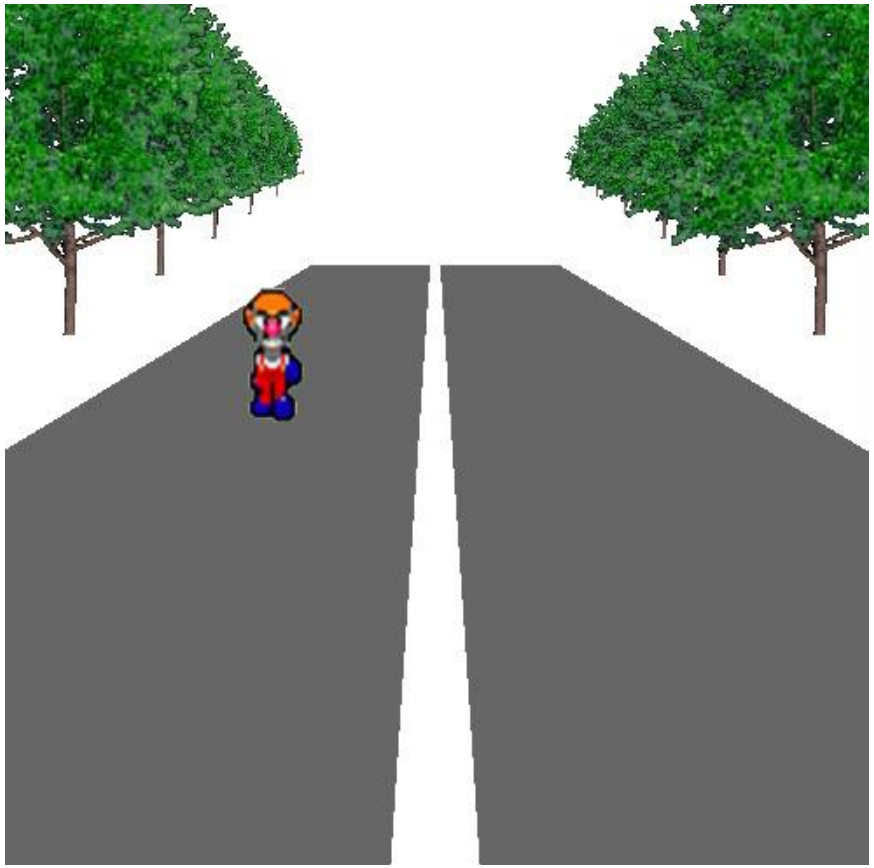
Basic Shader Applications

Point Sprites (GL_POINT_SPRITE) - 2D graphics



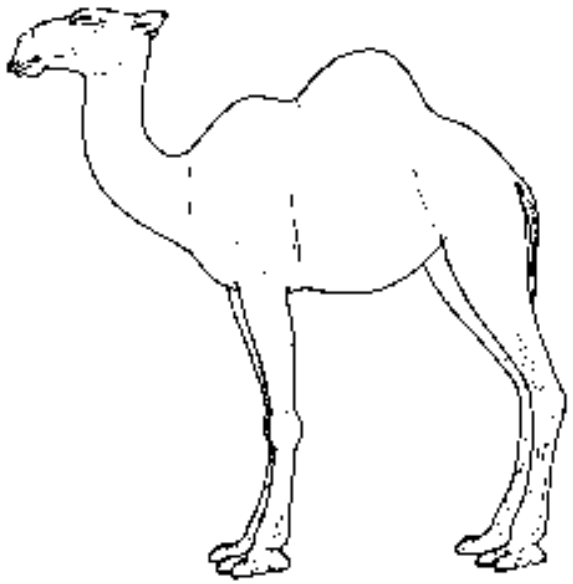
• particle system (2D)

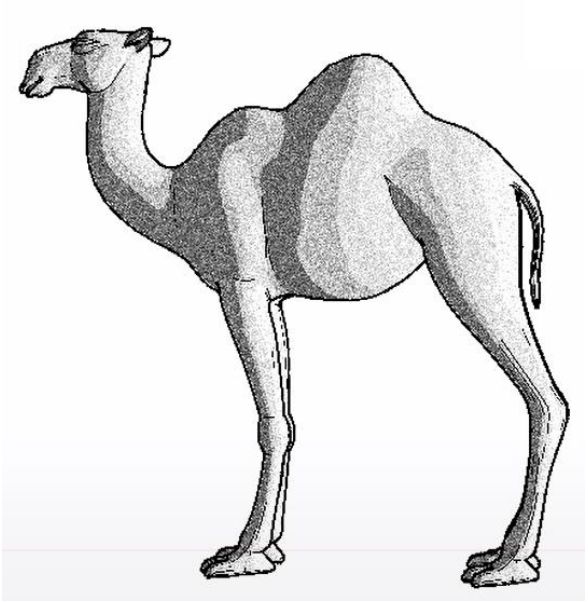
2D animation

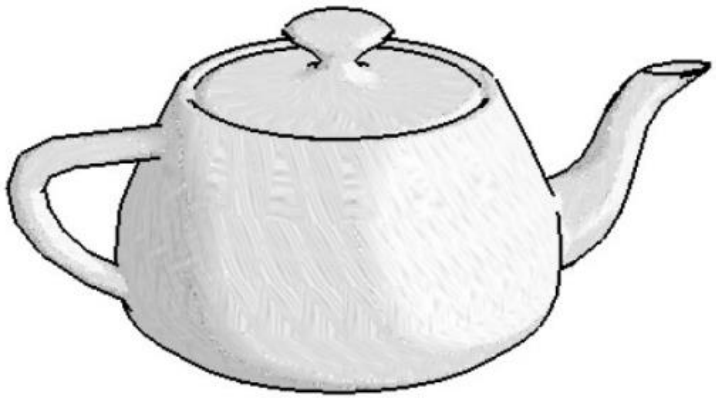


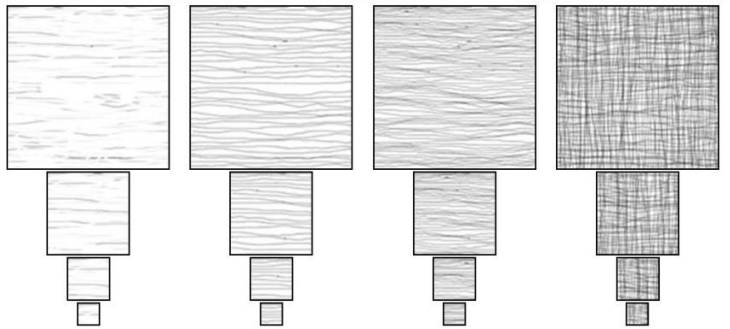
Non-Photorealistic Rendering

- pencil shading

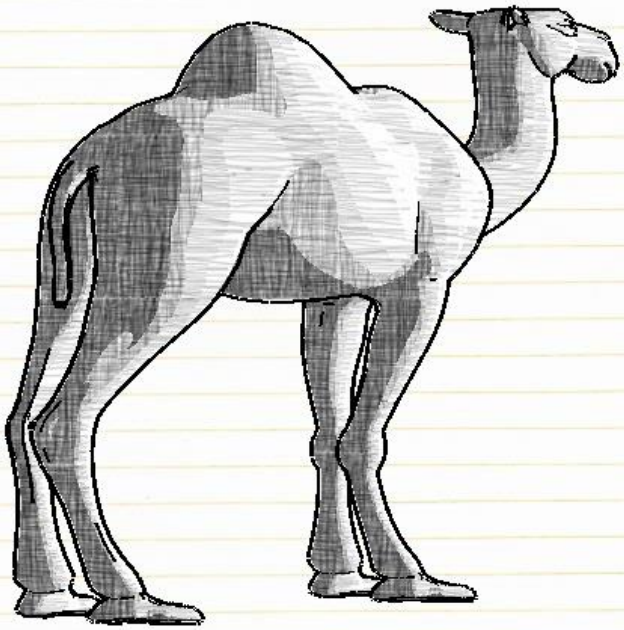








Non-Photorealistic Rendering

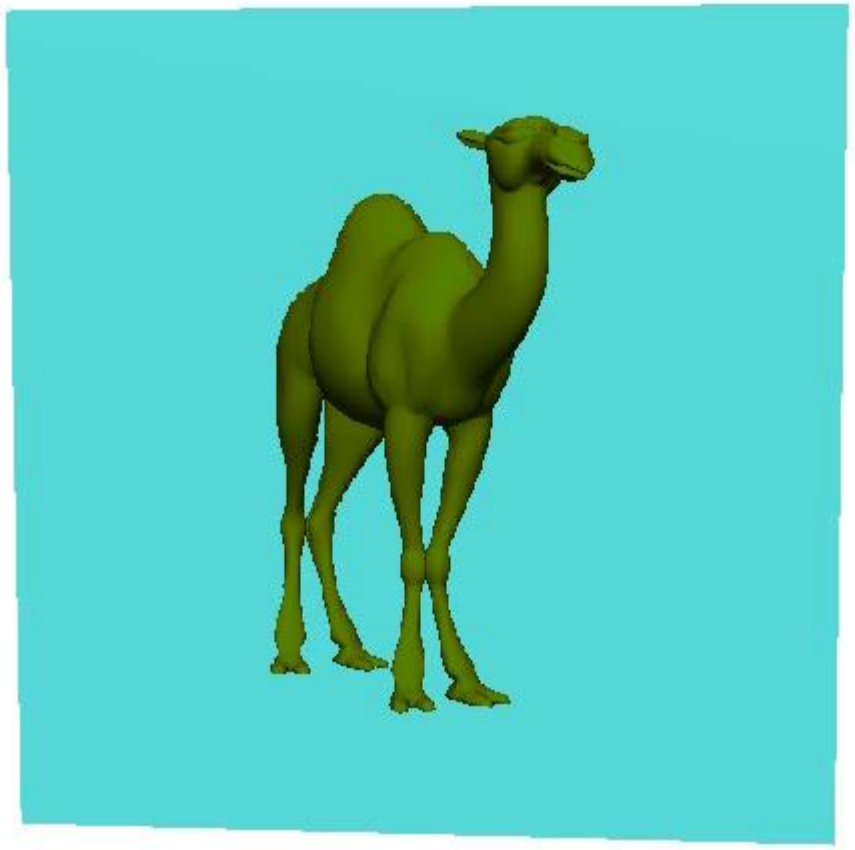


Render to Texture (RTT)

- creating an impostor (2D polygon)

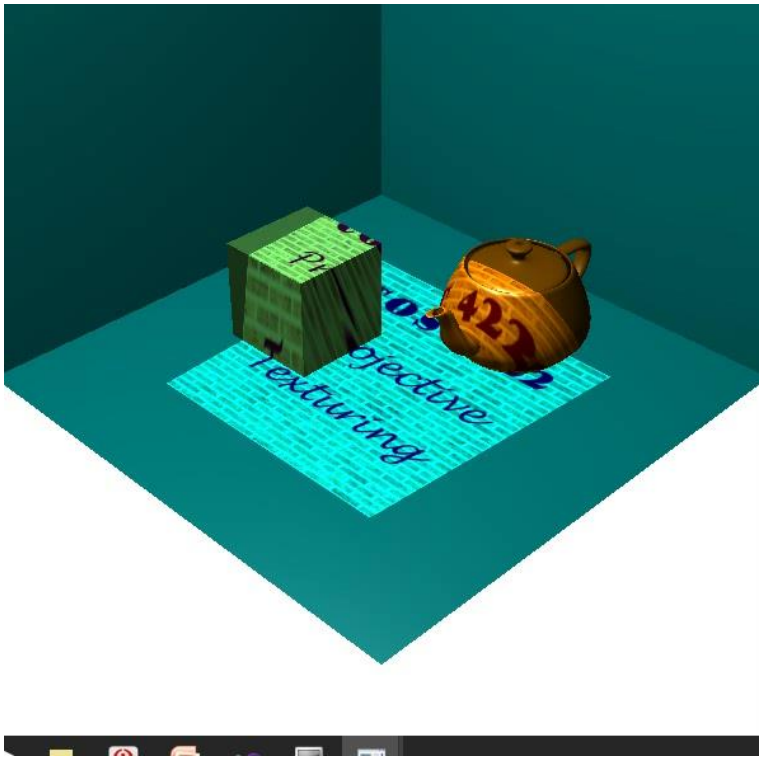
• Rendering a scene to a texture

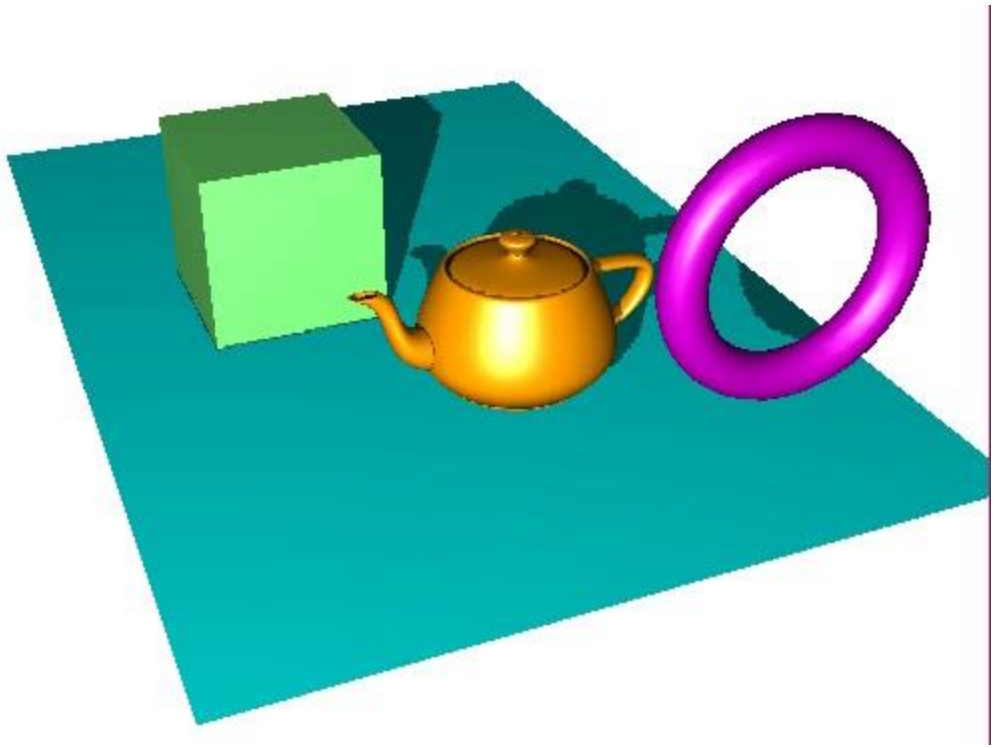
• Texture mapped on polygon.



Projective Texturing

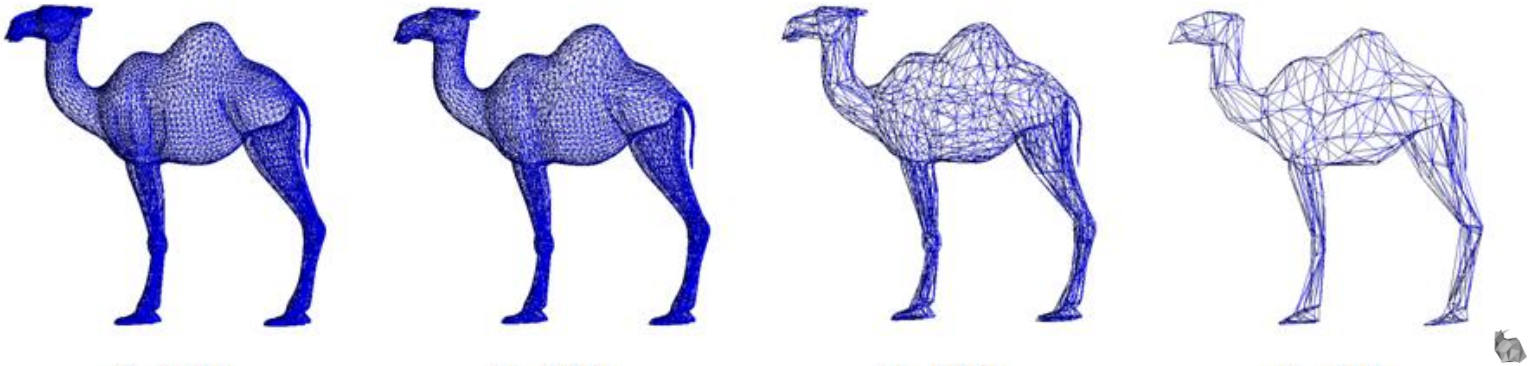
- generating complex shadows
  ↑ shadow map





Mesh Processing - Multiple levels of detail (Simplification)

- Simplification:



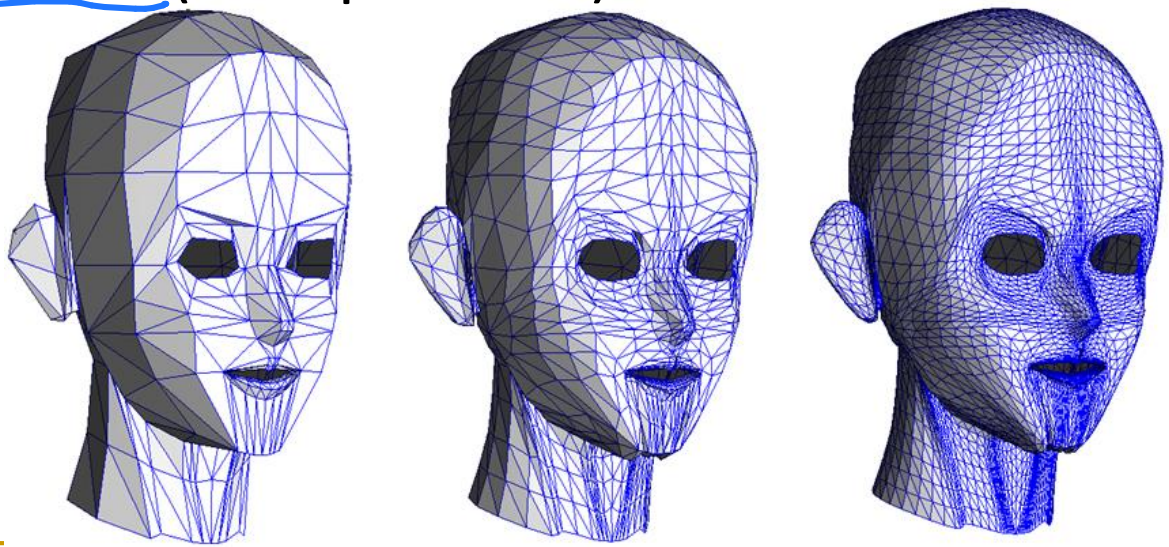
$V = 9000$
$F = 17996$
$E = 26994$

$V = 5000$
$F = 9996$
$E = 14994$

$V = 1000$
$F = 1996$
$E = 2994$

$V = 200$
$F = 396$
$E = 594$

- Subdivision (Interpolation):



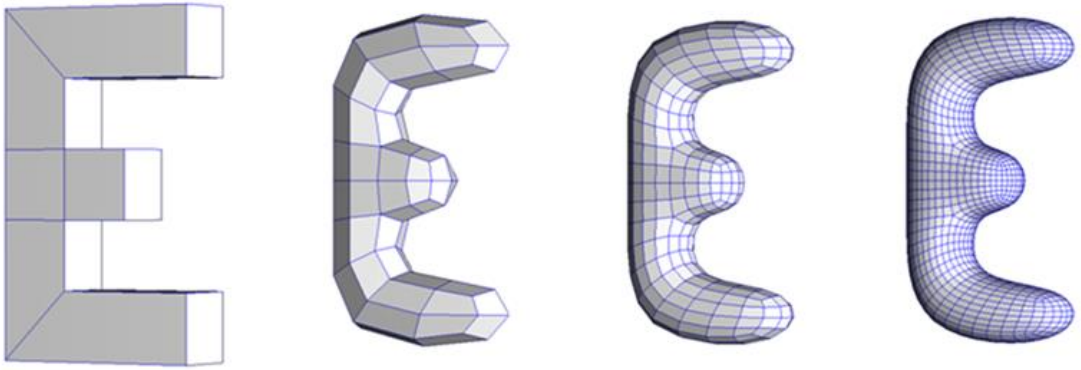
Iteration 0
504 triangles

Iteration 1
2016 triangles

Iteration 2
8064 triangles

Mesh Processing

- Subdivision (Approximation):



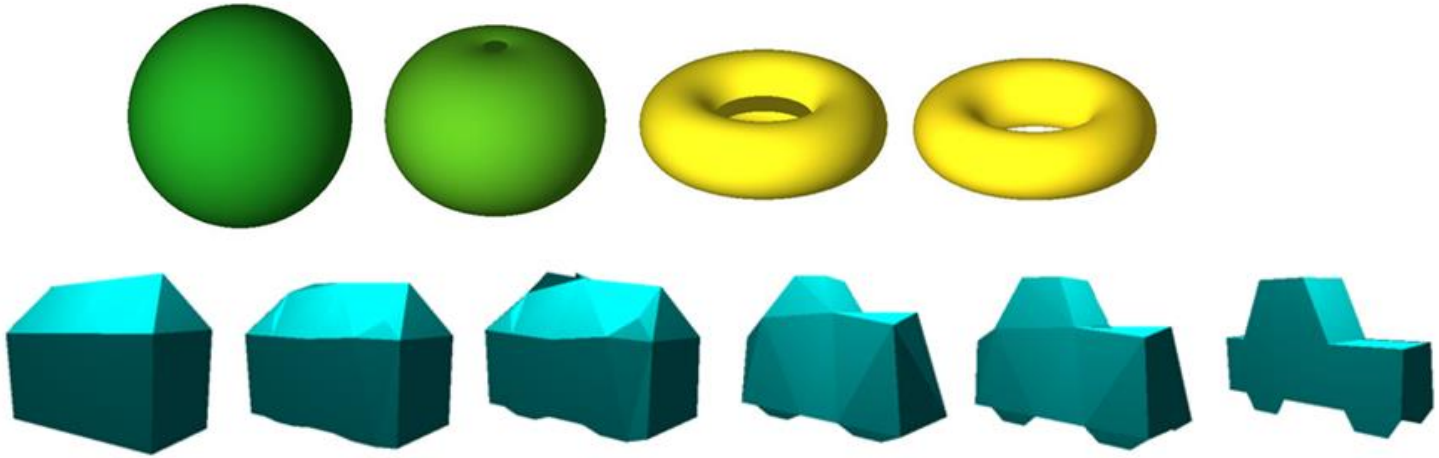
Original mesh
26 quads

Iteration 1
104 quads

Iteration 2
416 quads

Iteration 3
1664 quads

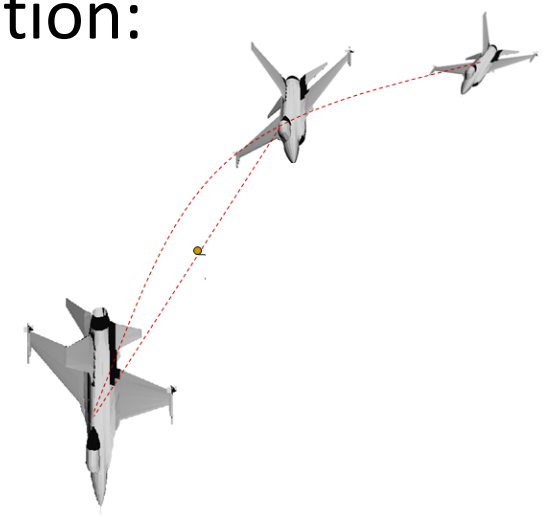
- Morphing



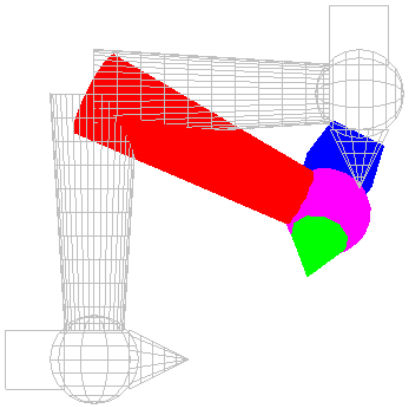
Quaternions – interpolating between orientations

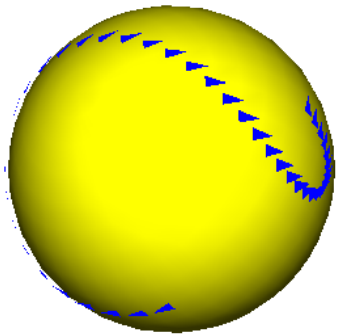
(q_0, q_1, q_2, q_3)

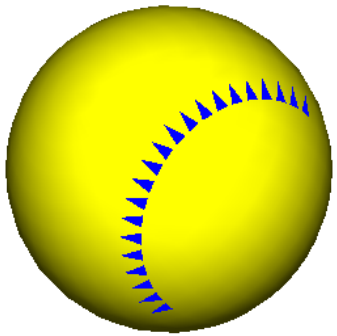
- Rotation Interpolation:



- Spherical Linear Interpolation:

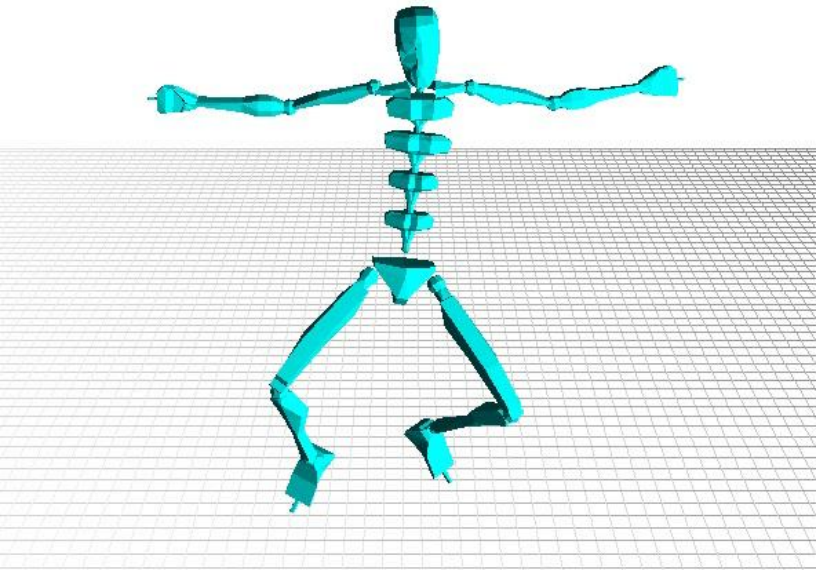


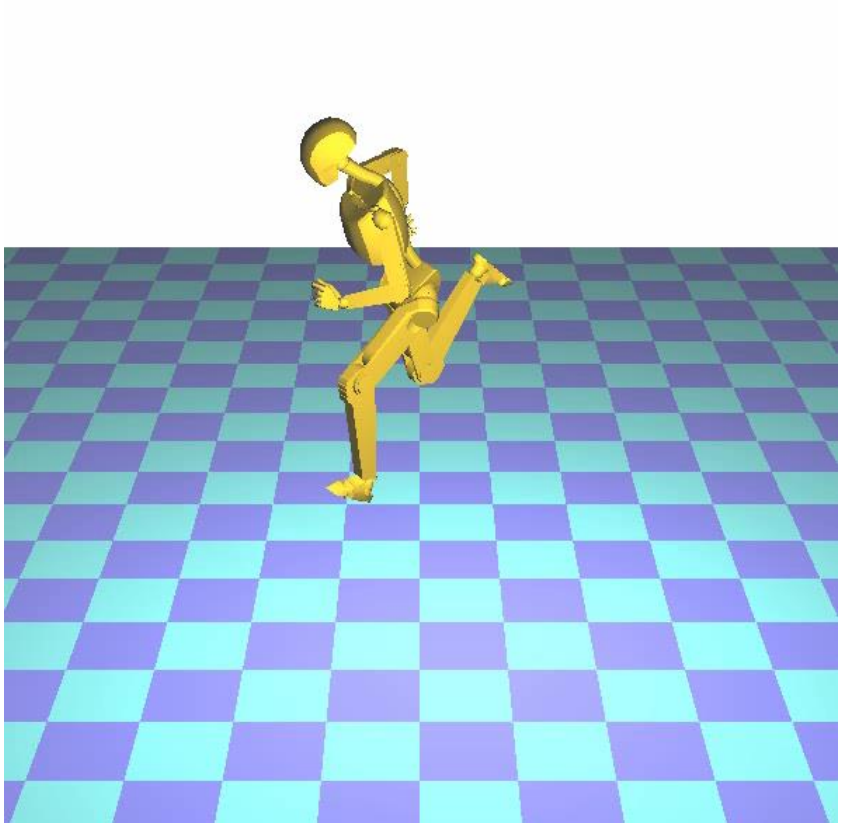




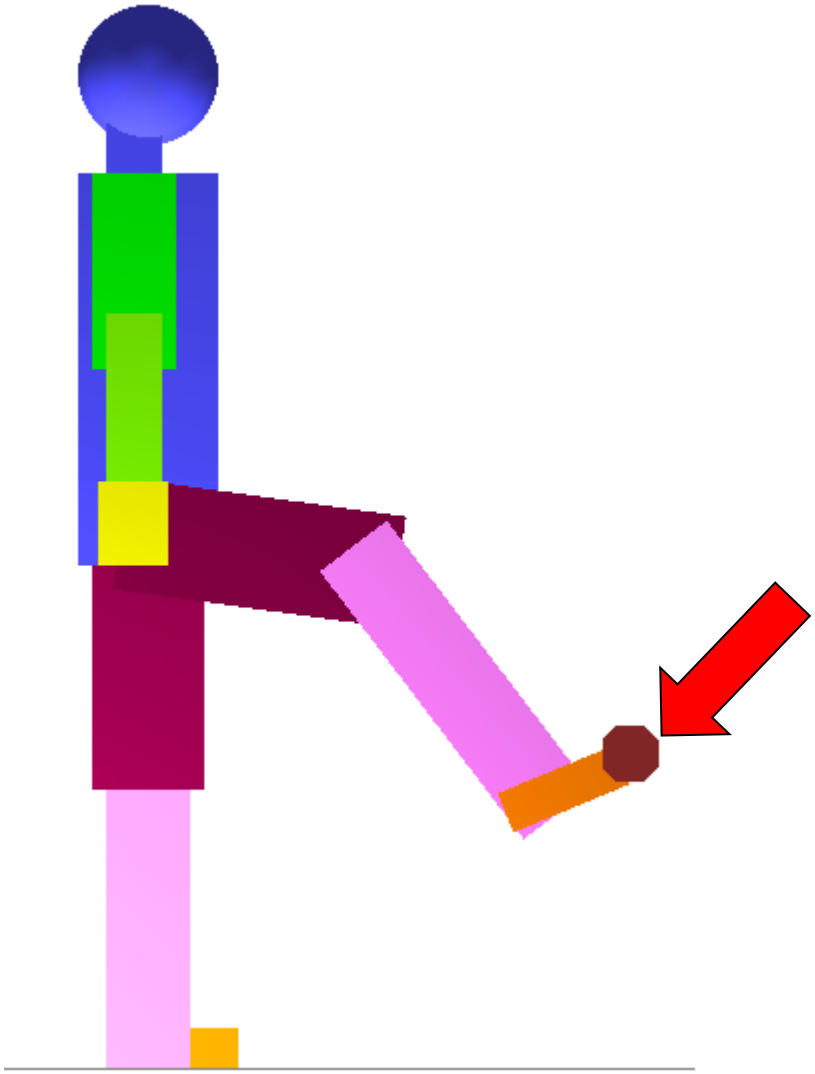
Motion Capture Data

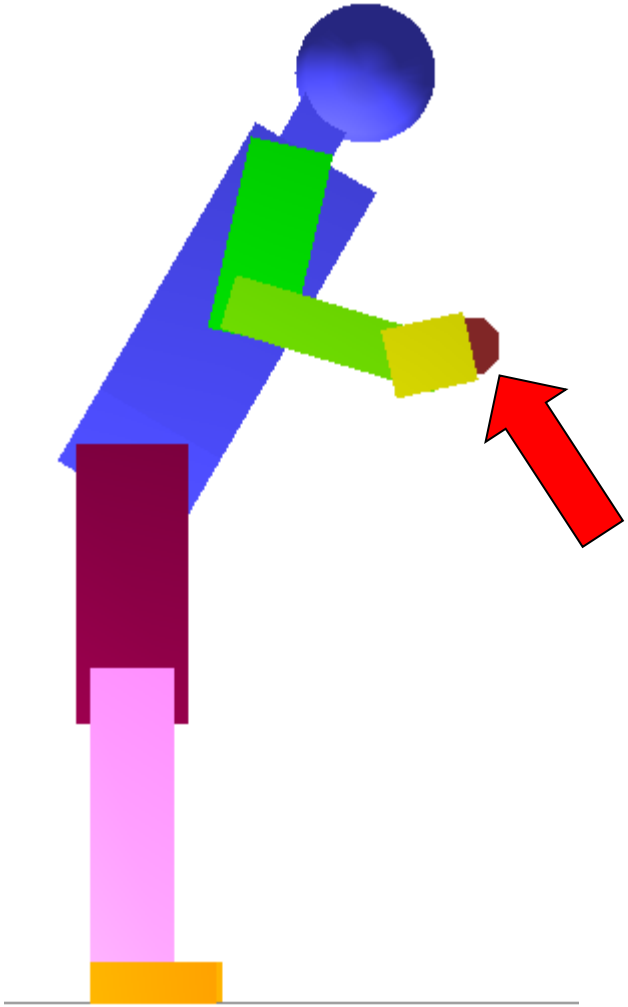
Skeletal Animation



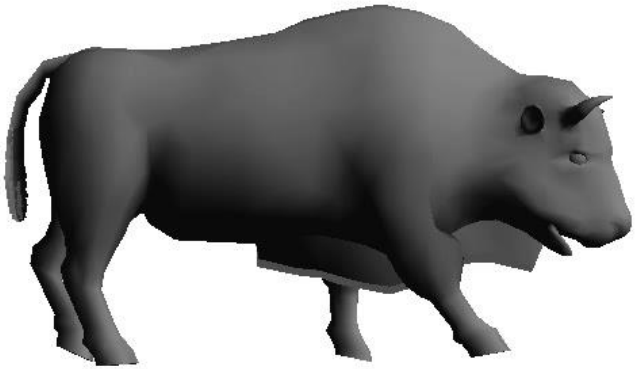


Inverse Kinematics

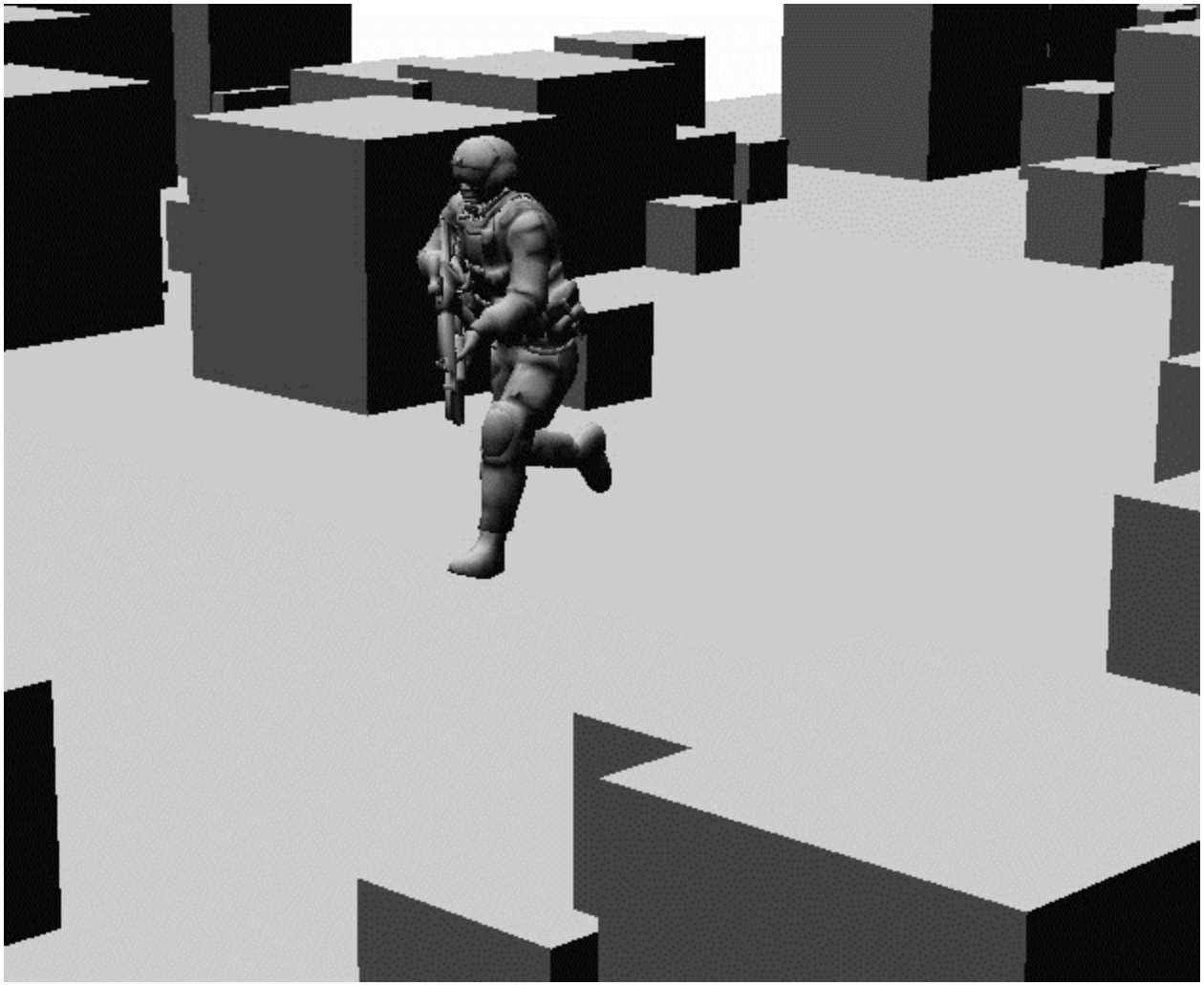


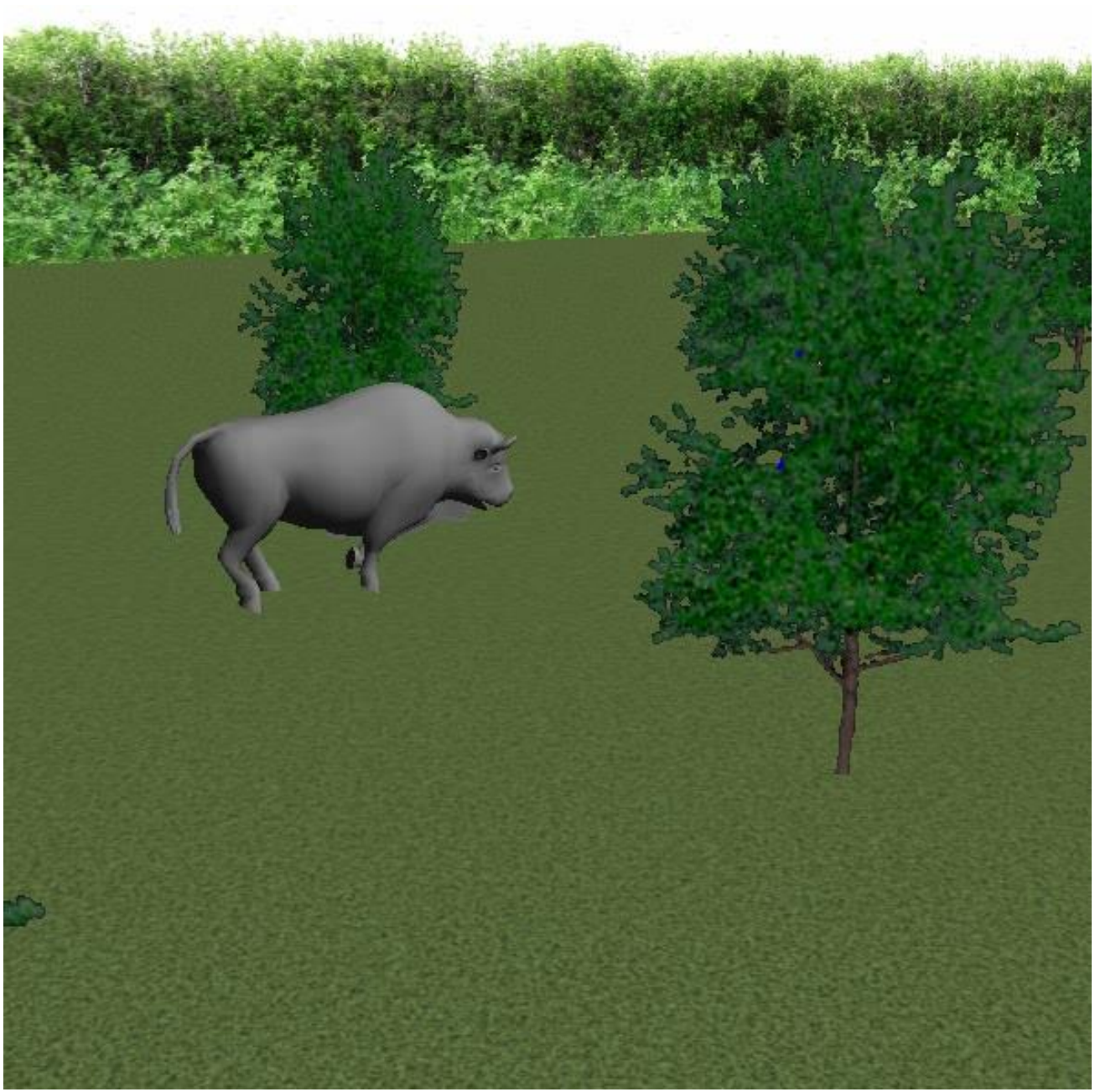


Character Animation



Character Animation





Reference Books

- A. Boreskov, E. Shikin, **Computer Graphics: From Pixels to Programmable Hardware**, CRC Press, 2014.
- Tom McReynolds, David Blythe, **Advanced Graphics Programming Using OpenGL**, Morgan Kaufmann Publ. 2005.
- John Kessenich, **OpenGL Programming Guide Version 4.5 (9th Ed.),** Addison Wesley, 2016.
- Tomas Moller and Eric Haines, **Real-Time Rendering**, A K Peters: Massachusetts, 3rd Ed, **2018**.

Reference Book

Mukundan, R. **Advanced Methods in Computer Graphics**, Springer 2012. (Full text access via Library)

Reference Book

Mukundan, R. **3D Mesh Processing and Character Animation**, Springer 2022.

https://www.springer.com/gb/book/9783030813536

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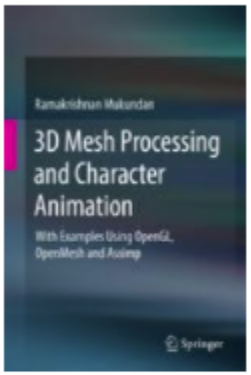

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3D Mesh Processing and Character Animation

With Examples Using OpenGL, OpenMesh and Assimp

Authors: **Mukundan**, Ramakrishnan

Includes a large collection of important methods used in the fields of three-dimensional mesh processing, tessellation and rendering

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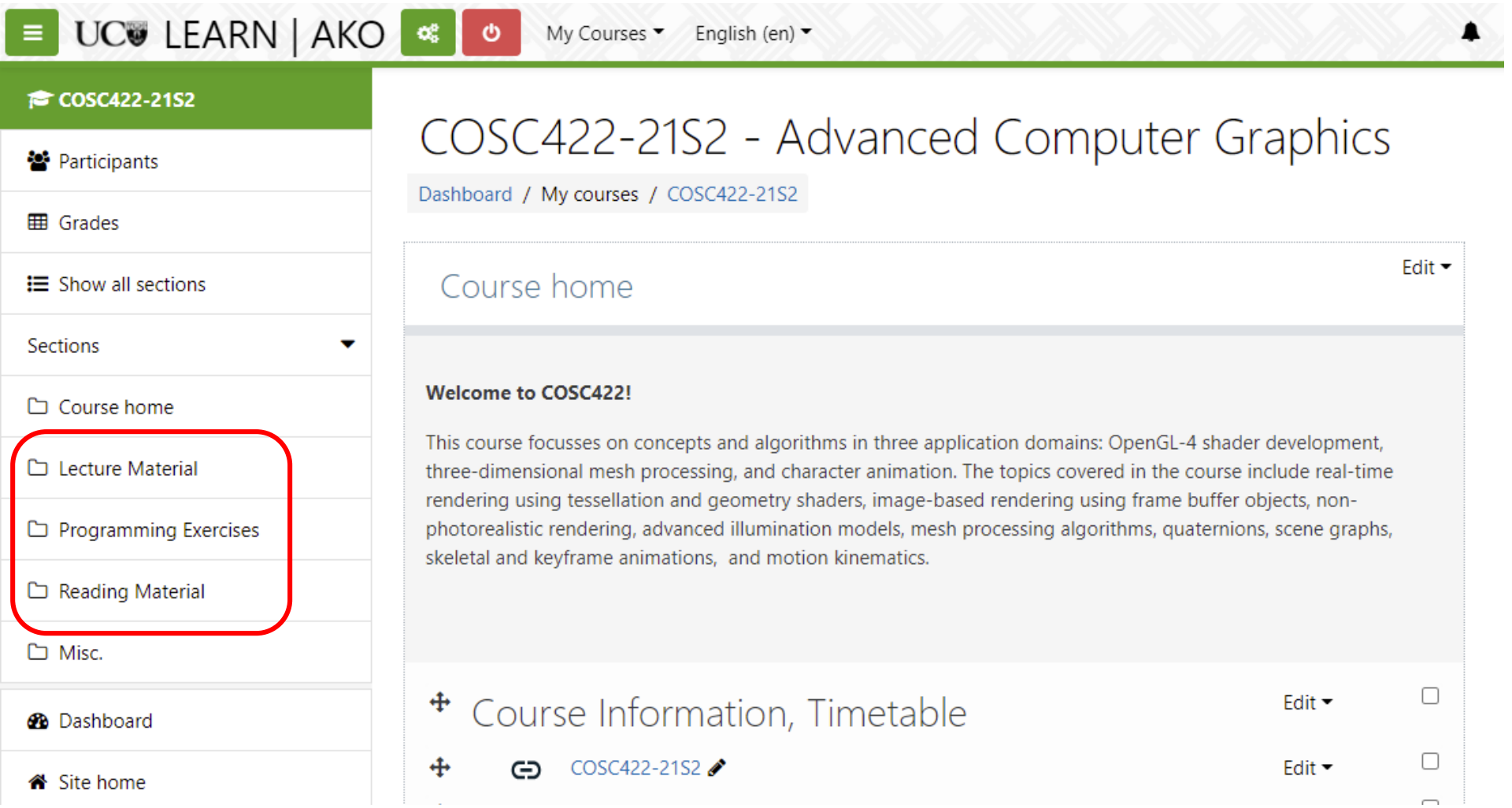
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Welcome to COSC422!
This course focusses on concepts and algorithms in three application domains: OpenGL-4 shader development, three-dimensional mesh processing, and character animation. The topics covered in the course include real-time rendering using tessellation and geometry shaders, image-based rendering using frame buffer objects, non-photorealistic rendering, advanced illumination models, mesh processing algorithms, quaternions, scene graphs, skeletal and keyframe animations, and motion kinematics.
Course Information, Timetable
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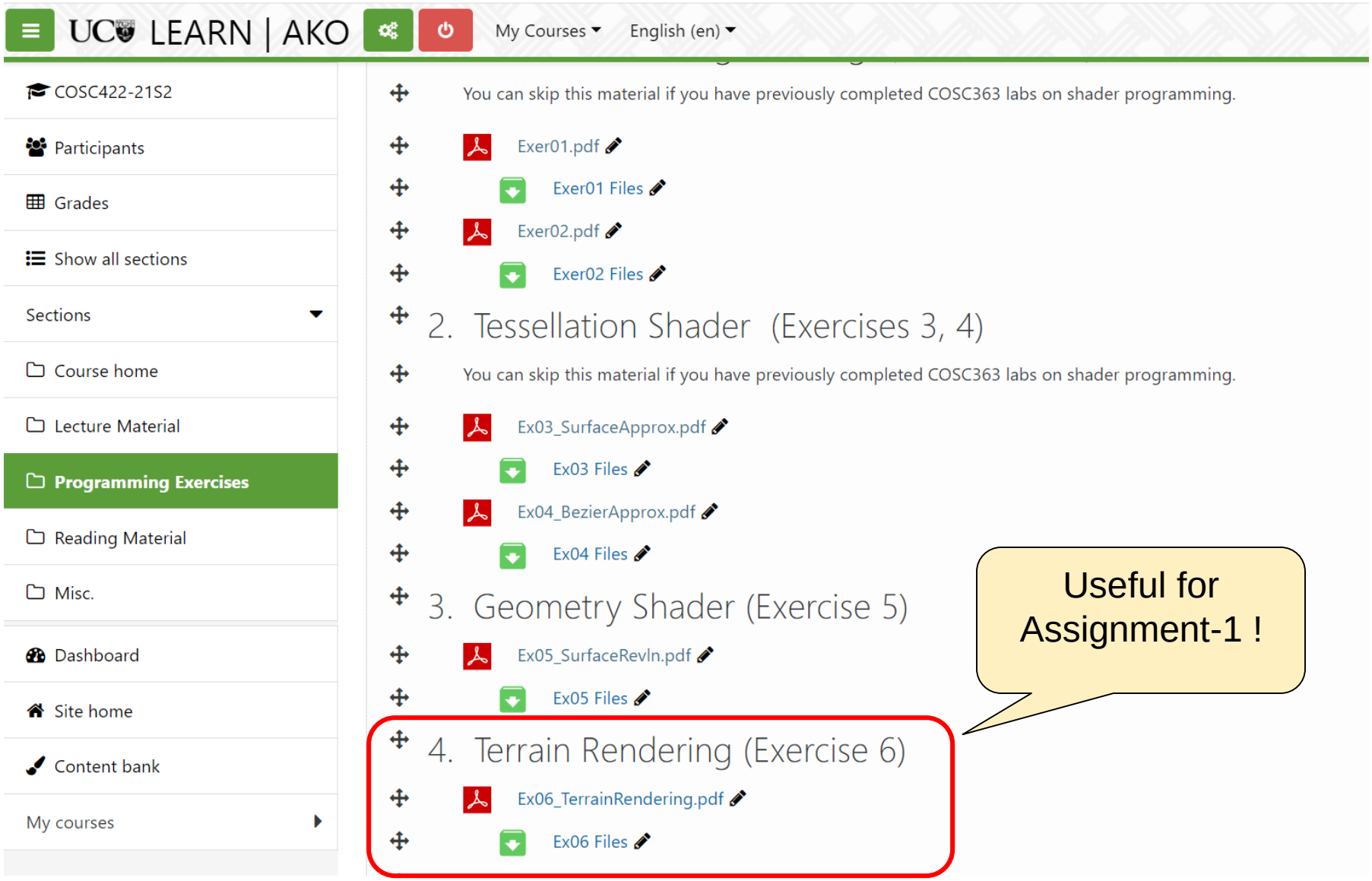
Programming Exercises



Reading Material