CS554 Geometric Modeling in Computer Graphics

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**Prerequisite:** Computer Graphics 450/550

**Description:**  
Advanced course in computer graphics focusing on representation and processing of polygonal models, and their applications in computer graphics. Topics include:  
- Surface fundamentals: discrete differential geometry and topology.  
- Data structures for representation of 3D surfaces.  
- Surface subdivision and smoothing.  
- Mesh simplification and multi-resolution representation of 3D surfaces.  
- Geometry compression.  
- Surface parameterization.  
- Geometry remeshing.  
- Topological simplification.  
- Implicit surfaces.

**Learning Objectives:**  
Upon completion of this course, students will have demonstrated the ability to:  
- Articulate important problems and applications in 3D modeling, such as shape representation, surface fairing, geometry compression, mesh parameterization, and geometry remeshing.  
- Develop proficiency with working on triangular meshes.  
- Formulate the theory behind Laplacian smoothing, and implement surface fairing based on discrete Laplacian.  
- Perform Loop-subdivision on triangular meshes.  
- Describe the process of mesh simplification and error metrics that are often used.  
- Implement efficient data structures and algorithms that support surface traversal.  
- Enunciate major approaches for geometry compression.  
- Compute mesh parameterization.  
- Perform discrete curvature estimation on surfaces  
- Articulate the process for anisotropic remeshing.  
- Describe how surface topology, such as the Euler characteristic, is related to geometry processing on surfaces.

**Topics:**  
- Surface fundamentals:  
  - Surface topology.  
  - Discrete differential geometry.  
- Triangular mesh representation of 3D surfaces:  
- Subdivision and Smoothing:  
  - Loop subdivision.
• Smoothing based on Gauss filtering.

• Mesh simplification and level-of-detail presentation:
  o Edge collapse and quadric measure.
  o Progressive mesh presentation.

• Compression:
  o Edgebreaker compression and decompression.

• Surface parameterization.

• Geometry remeshing:
  o Isotropic remeshing.
  o Anisotropic remeshing.

• Surface topology:
  o Morse theory and Reeb graph.
  o Topological simplification.

• Implicit surfaces:
  o Representation.
  o Morphing.

Textbooks (recommended, but not required):
• OpenGL Programming Guide, 2nd Edition [Woo, Neider, Davis]

Reading Materials:
A collection of recent papers in the field of geometric modeling.

Projects and Grading:
This course is primarily project based. Each student will complete 3 independent projects plus a term project to be discussed later. Class attendance is required.

• Putting a 3D checkerboard pattern on surfaces, and Loop subdivision 15%
• Curvature and quadric measure estimation, and surface smoothing 10%
• Surface parameterization via face clustering and conformal mappings 25%
• Term project & class presentation 50%

Term Project Ideas (some examples):
• Heat diffusion over 3D surfaces and conformal parameterizations.
• Topological noise removal.
• Shape matching.
• View-dependent hatching on surfaces.
• Example-based texture synthesis, such as “lapped textures”.
• Subdivision surfaces.
Late Policy
Late assignments will be marked off 10% for each weekday that it is late.

Tentative Schedule

<table>
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<tr>
<th>Week</th>
<th>Topics</th>
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| 1    | Introduction to 3D modeling and geometric processing.  
      | Surface fundamentals.  
      | A popular data structure for representing 3D meshes: .ply format.  
      | Display a triangular mesh with OpenGL.  
      | **Assign#1 Out** |
| 2    | Loop subdivision.  
      | Discrete curvature estimation.  
      | Surface smoothing using Gaussian filters. |
| 3    | Mesh simplification and Multi-resolution representations.  
      | **Assign#1 Due**  
      | **Assign#2 Out** |
| 4    | Geometry compression. |
| 5    | Surface parameterization.  
      | **Assign#2 Due**  
      | **Assign#3 Out** |
| 6    | Surface parameterization (continued). |
| 7    | Remeshing.  
      | **Assign#3 Due** |
| 8    | Subdivision surfaces. |
| 9    | Implicit surfaces. |
| 10   | Point-based modeling. |
| Finals | **Term Project Due**  
      | No Exam Scheduled  
      | Demonstration & Grading of Term Projects |

Academic Dishonesty
Please do your own work. The default consequence for academic dishonesty is a failure for the course. It is okay to discuss with other students general ideas about implementing a program. It is not okay to copy another student's program. It is okay to discuss possible program bugs. It is not okay to debug another student's program.

Expectations
Students are expected to attend lectures, participate in the discussions, and work with their group members on group projects. You should come to class prepared and speak up when something is not clear. Being prepared means completing the assigned reading and assignments. Students are expected to be creative and have fun!
Students with documented disabilities who may need accommodations, who have any emergency medical information the instructor should be aware of, or who need special arrangements in the event of evacuation, should make an appointment with the instructor as early as possible, and no later than the first week of the term. Class materials will be made available in an accessible format upon request.