# CSE 631: PHYSICS-BASED MODELING FOR VISUAL COMPUTING

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# Important Information

- When: TuTh 11:20am — 12:40pm
- Where: Social and Behavioral Sciences N107 (it is possible that we will move to our CS Seminar Room (Rm.1306) after the first lecture).
- Office hours: TuTh 12:40pm — 2:40pm, or by appointment!
- Credits: 3
- How can I get a “A”?
  - NO midterm
  - NO final exam
  - ASSIGNMENTS and COURSE PROJECT!
- Two types of assignments
  - paper presentation
  - programming

# Course Synopsis

- Objectives —
  Physics-based simulation methodology
  Integrated approach for visual computing
- Concepts and Framework
- Mathematical techniques
- Geometric computing
- Computational physics
- Numerical techniques
- A wide spectrum of applications

# CSE631 vs. CSE530

- Above entry-level graduate course
- Open to everyone!
- MS projects
- Ph.D oriented and research driven
- Case studies through paper presentation
- Additional handouts from various books
- Pro-active involvement from students
- Different mechanism for course grade
- Group project is encouraged
- Higher standard

# Course Facts

- This is an advanced graduate course!
- Can I take this course? YES, if YOU
  - are a graduate student with CS background
  - talk to the instructor
  - have graphics/visualization background
  - familiar with calculus/algebra/geometry
  - have basic knowledge on numerical analysis
  - understand simple physical laws
- You do NOT need to take CSE528 or CSE530 prior to this course
- Having knowledge from CSE528 or CSE530 makes it much better
- However, you need to have taken CSE328, or CSE332, or equivalent courses elsewhere
- Lectures: paper presentation

- Class attendance is critical!
- No textbooks

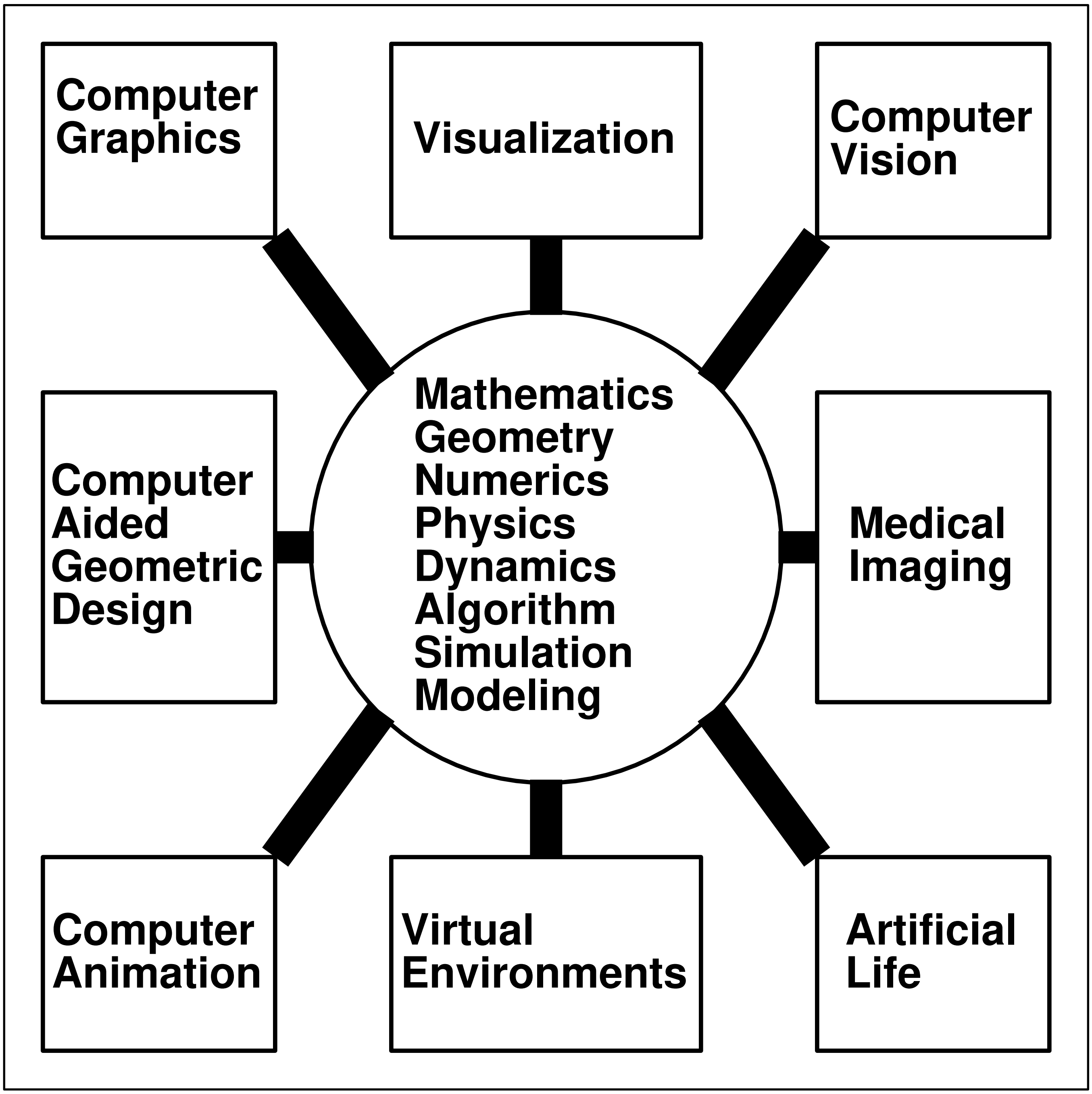
# Course Facts

- Students are expected to
  - present several papers
  - finish one course assignment
  - complete one course project
  - present your project in the class
  - give system demonstration
  - submit the final report
- What projects are appropriate?
  - talk to Hong
  - projects available from Hong
- Pathway to success
  - highly-motivated
  - hard-working
  - start ASAP
  - meet with Hong on a regular basis
  - actively interact with your fellow students
  - visit CS library frequently

# Course Facts

- NOT a graphics/visualization course
- NOT a course to teach OpenGL
- Do NOT teach graphics (basic knowledge & programming skills should be acquired elsewhere)
- Learn fundamental algorithms and advanced techniques!
- Study various visual computing applications
- Course projects lead to MS thesis (project) or Ph.D dissertation topics

# What will be covered



# Paper Resources

- Access libraries for Journals and conferences' proceedings

- Relevant journals:
  ACM TOG, IEEE TVCG, IEEE CG&A, CAD,
  CAGD, Graphical Models, The Visual
  Computer, Computer Graphics Forum,
  IEEE PAMI, IJCV, IEEE Transactions on
  Medical Imaging, etc.

- Major conferences:
  Siggraph, Visualization, Eurographics,
  Pacific Graphics, Graphics Interface,
  Solid Modeling, Shape Modeling,
  ACM I3D Symposium, ICCV, CVPR, etc.

# Grading Schemes

- **NO MIDTERM, NO FINAL EXAM.**
- 100% **on ASSIGNMENT/PROJECT**
- **Individual project (one student), or**
- **Group project (two students)**
- **Paper presentation:** 20%
- **Assignment:** 10%
- **Course project:** 70%
  - **two-page project proposal** (20%)
  - **preliminary demonstration** (10%)
  - **oral presentation and final demonstration** (20%)
  - **project report (10–20 pages) + software** (50%).
- **Target dates**
  - **warm-up assignment — 3rd week**

– paper presentation —— throughout the semester
– proposal —— 5th week
– mid-term demo —— 8th week
– final presentation —— at the end of the semester
– project report —— at the end of the semester

- Group project

# Project Requirements

- Interactive interface (graphics-based)
- Intuitive and easy to understand
- Efficient (fast, high-performance)
- Basis functionalities
- Examples
- Flexible and easy to generalize
- Project plan (multiple check-points and phases)
- Individual or group project
- Office hours / individual meetings
- Penalty for late submission

# Outline

- Geometric and solid modeling
- Physics-based modeling
- Deformable models
- Mathematics
- Numerical Solutions
- Visual computing applications
  - Graphics
  - Vision
  - Geometric Design
  - Visualization
  - Virtual environments

# Geometric and Solid Modeling

- Polygonal meshes
- Polynomials and splines
- Parametric curves and surfaces
- Bezier
- B-splines and NURBS
- Triangular & irregular patches
- multisided surfaces
- Subdivision objects
- Manifold splines
- Implicit functions
- CSG and volumetric models

- Wavelets and hierarchical models
- Special shapes
  - ruled surface
  - developable surface
  - offset
  - sweeping
  - swung surface
  - surface of revolution
- Solid Models
  - Constructive solid geometry (CSG)
  - Boundary representation (B-rep)

# Geometric Operations

- Trimming
- Intersection
- Approximation
- Interaction
  - control point
  - weight
  - knot vector
- Interpolation
  - scattered data
  - curve network
  - regular dataset
- Constraints
  - shape-preserving
  - convex-preserving

- Fitting
- Continuity
- Optimization
- Computation Geometry
- Differential Geometry
- Efficient Algorithm

# Physical Models

- Rigid & nonrigid models
- Mass-spring lattices
- Parameterized models
- Elastic & inelastic bodies
- Dynamic B-splines & NURBS
- Dynamic subdivision models
- Particle systems & fluid models
- Superquadric geometry
- Snakes: dynamic contour models
- Symmetric models
- Finite elements

# Geometric Modeling Techniques

- Interpolation
- Approximation
- Optimization
- Interaction
- Forces
- Constraints
- Dynamic sculpting
- Continuity
- Differential geometry
- Hierarchical techniques
- Level of Details

- **Simplification**

# Dynamic Modeling

- Mass, damping, elastic Energy
- Internal and external forces
- Geometric constraints
- Optimal control of physical models
- Lagrange mechanics
- mathematical physics
- Multi-body (rigid and nonrigid) simulation
- local and global deformations
- Viscoelasticity, plasticity, fracture
- Thermoelasticity, the heat heat transfer, Melting
- Fluid dynamics

# Numerics

- Linear algebra & matrix computation
- Linear & nonlinear systems
- Static & dynamic problems
- Initial-value & boundary-value problems
- The finite difference method
- The finite element method
- Calculus of Variations
- Direct & iterative methods
- Differential equations of equilibrium
- Numerical analysis
- Multiresolution algorithms

# Visual Computing Applications

- Morphing and image warping
- Surface blending and solid rounding
- Animation and simulation
- Freeform deformation
- Reverse engineering
- Shape reconstruction
- Sparse data fitting
- Interactive sculpting
- Model simplification
- Object motion tracking
- Feature extraction and segmentation

- Visualization
- Variational design
- Shape interrogation and control
- Biomedical imaging
- Interface and virtual environments
- Texture mapping
- Artificial Life
- Plastic surgery
- Natural phenomenon

# Graphics

- *Computer Graphics*,
  **Hearn and Baker, 2nd edition,**
  **Prentice Hall, 1997.**

- *Computer Graphics: Principles and Practice*,
  **James D. Foley, Andries van Dam, Steven K. Feiner,**
  **and John F. Hughes, 2nd edition,**
  **Addison Wesley, 1990.**

- *Computer Graphics*,
  **Alan Watt, 2nd edition,**
  **Addison-Wesley, 1993.**

# Geometric Modeling


- *Curves and Surfaces for Computer Aided Geometric Design A Practical Guide*, **3rd edition,**
  **G. Farin, Academic Press, 1993.**

- *An Introduction to Splines for use in Computer Graphics and Geometric Modeling*,
  **R.H. Bartels, J.C. Beatty, and B.A. Barsky, Morgan Kaufmann Publishers, Inc., 1987.**

- *Computational Geometry for Design and Manufacture*,
  **I.D. Faux and M.J. Pratt, Ellis Horwood, Chichester, England, 1979.**

- *Geometric and Solid Modeling: An Introduction*,
  **C.M. Hoffmann, Morgan Kaufmann Publishers, Inc., San Mateo, CA, 1989.**

- *Differential Geometry of Curves and Surfaces*,
  **M.P. do Carmo, Prentice–Hall, Englewood Cliffs, NJ, 1976.**

# Mathematics


- *Introduction to Applied Mathematics*, **G. Strang, Wellesley Cambridge Press, 1986.**

- *Mathematical Programming Theory and Algorithms*, **M. Minoux, John Wiley and Sons, 1986.**

- *Numerical Recipes: The Art of Scientific Computing*, **W.H. Press, B.P. Flannery, S.A. Teukolsky, and W.T. Vetterling, Cambridge University Press, Cambridge, UK, 1986.**

- *Computer-Oriented Mathematical Physics*, **D. Greenspan, Pergamon Press, Oxford, 1981.**

- *Methods of Mathematical Physics*, **Vol I, R. Courant and D. Hilbert, Interscience, London, 1953.**

- *Classical Mechanics, 2nd Ed.*, **H. Goldstein, Addison-Wesley, Reading, MA.,1980.**

- *The Finite Element Method (Third Edition)*,
  **O.C. Zienkiewicz, McGraw–Hill, London, 1977.**

- *The Finite Element Handbook*,
  **H. Kardestuncer and D.H. Norrie,**
  **McGraw-Hill, 1987.**

- *The Finite Element Method Displayed*,
  **G. Dhatt, Chichester [West Sussex];**
  **New York, 1984.**

- *Finite Element Procedures*,
  **K.-J. Bathe, Prentice Hall, 1996.**

# What Will Be Covered Next?

- **Parametric representation for curves and surfaces**
- **"A survey of curves and surfaces in CAGD",**
  **W. Bohm et al.**
  *Computer Aided Geometric Design*, **1(1), 1-60**