Lec 0: Course Logistics

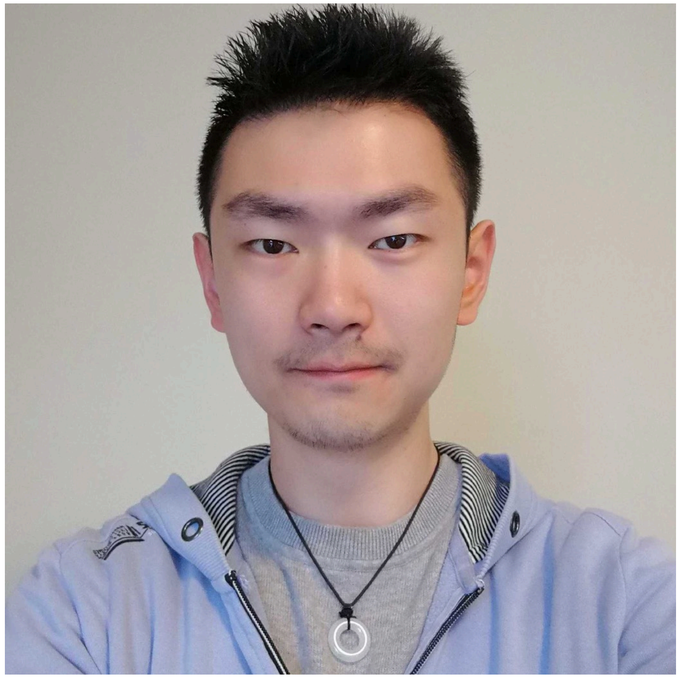
15-369/769: Numerical Methods (Foundations, ML, & Visual Computing)

Instructor: Minchen Li

Course Staff

Instructor

- Minchen Li
  - Assistant Professor, CSD
  - minchenl@cs.cmu.edu
  - Office hour by appointment



Course Staff

Teaching Assistant

- Zhaofeng Luo
  - PhD student, CSD
  - zhaofen2@andrew.cmu.edu
  - Office hour TBD



Why Numerical Computing?

- Solves complex problems that have no closed-form solutions.
- Simulate complex processes in science and engineering.
- Enables scalable data and ML algorithms.
- Links mathematical theory to practice.
- Builds computational and algorithmic skills.

The potentials of numerical computing are limitless!

Why Numerical Computing?

Limitless Potentials



Next-Level Entertainment & Social



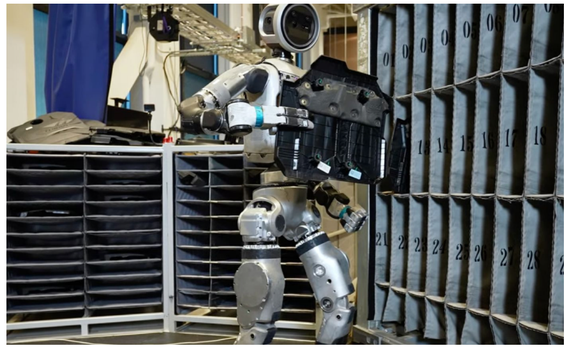
Immersed Education & Training



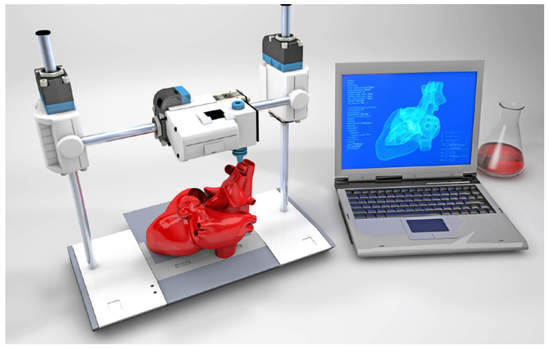
Virtual Try-On



Digital Twin Factory



Robot Learning



Computational Fabrication



Virtual Surgery

More to be explored by you!

Why Numerical Computing?

Fundamental Challenges

- Trade-offs, between
  - Computational costs
  - Quality of results, e.g. robustness, accuracy, etc.
- Data acquisition, e.g.:
  - Data instances
  - Model parameters

A little more about Minchen

- PhD in Computer Science, UPenn, 2020
- Joined CMU since Fall 2023
- Research group at CMU: **Simulation Intelligence Group (SIG)**
- Research focus:
  - efficient and reliable solid/fluid simulation and
  - simulation-ready 3D/4D generation
  - *for visual computing, robotics, and manufacturing*
- More: https://www.cs.cmu.edu/~minchenl/



SIGGRAPH 2026
Los Angeles 19–23 JUL

Robust and Efficient Penetration-Free Elastodynamics without Barriers



Juntian Zheng[1] Zhaofeng Luo[1] Minchen Li[1, 2]

Carnegie Mellon University 1

Genesis AI 2

Guying Lin† , Kemeng Huang† , Michael Liu† , Ruihan Gao, Hanke Chen† , Lyuhao Chen, Beijia Lu, Taku Komura, Yuan Liu, Jun-Yan Zhu, Minchen Li. PAT3D: Physics-Augmented Text-to-3D Scene Generation. International Conference on Learning Representations (ICLR), 2026.

Introducing

Now it’s your turn to introduce yourself!

What’s your name?
What year and program are you in?
Why did you choose this course?
Anything else you’d like to share?

Tentative Syllabus

Schedule

- 20 lectures in total (excluding this one)
  - 2 for each assignment
- In-class midterm and final exams (+ in-class reviews)
- No class:
  - Labor Day,
  - Fall Break, and
  - The Thanksgiving **WEEK**!

- **Week 1**
  - (Aug 24) Lec0: Course Logistics
  - (Aug 26) Lec1: Mathematics Review
- **Week 2**
  - (Aug 31) Lec2: Numerics and Error Analysis
  - (Sep 2) Lec3: Linear Systems and the LU Decomposition
  - A1 due Sep 6 at 23:59 ET
- **Week 3**
  - (Sep 7) *Labor Day, no class*
  - (Sep 9) Lec4: Designing Linear Systems
  - A2 due Sep 13 at 23:59 ET
- **Week 4**
  - (Sep 14) Lec5: Analyzing Linear Systems
  - (Sep 16) Lec6: Column Spaces and QR
  - A3 due Sep 20 at 23:59 ET
- **Week 5**
  - (Sep 21) Lec7: Eigenvectors
  - (Sep 23) Lec8: Singular Value Decomposition
  - A4 due Sep 27 at 23:59 ET
- **Week 6**
  - (Sep 28) Lec9: Nonlinear Systems
  - (Sep 30) Lec10: Unconstrained Optimization I
  - A5 due Oct 4 at 23:59 ET
- **Week 7**
  - (Oct 5) Midterm Review
  - (Oct 7) In-Class Midterm Exam
- **Week 8:** *Fall Break, no classes*
- **Week 9**
  - (Oct 19) Lec11: Unconstrained Optimization II
  - (Oct 21) Lec12: Constrained Optimization
  - A6 due Oct 25 at 23:59 ET
- **Week 10**
  - (Oct 26) Lec13: Iterative Linear Solvers
  - (Oct 28) Lec14: Specialized Optimization Methods I
  - A7 due Nov 1 at 23:59 ET
- **Week 11**
  - (Nov 2) Lec15: Specialized Optimization Methods II
  - (Nov 4) Lec16: Interpolation
  - A8 due Nov 8 at 23:59 ET
- **Week 12**
  - (Nov 9) Lec17: Integration and Differentiation
  - (Nov 11) Lec18: Ordinary Differential Equations
  - A9 due Nov 15 at 23:59 ET
- **Week 13**
  - (Nov 16) Lec19: Partial Differential Equations I
  - (Nov 18) Lec20: Partial Differential Equations II
  - A10 due Nov 22 at 23:59 ET
- **Week 14**: *Thanksgiving, no classes*
- **Week 15**
  - (Nov 30) Final Review
  - (Dec 2) In-Class Final Exam

Tentative Syllabus

What is this course about? — Style

- We will focus on introducing the main concepts, basic methods, and a bit about the practicality and state-of-the-art methods.

- Some discussions on key **derivations**, **algorithms**, and **implementations.**

- We will also briefly mention existing open-source code/libraries.

Tentative Syllabus

What is not covered in this course?

- Hardcore parallel computing, e.g. GPU programming
- Large-scale numerical methods
- Hardcore physics-based simulation (numerical solutions to PDEs)
- Hardcore stochastic methods, e.g. Monte-Carlo PDE solvers

- Some of these are covered in
  - 15-763: Physics-Based Animation of Solids and Fluids
  - 15-327: Monte Carlo Methods and Applications

Recommended Prerequisite

- Programming (Python)
  - numpy, pygame
- Vector Calculus
  - vector derivatives, e.g. gradient, divergence, curl
- Linear Algebra
  - Basic vector/matrix operations, matrix factorization, linear solvers, …

Grading

- Assignments: 75% (7.5% each)
  - Written + Programming
  - Designed to be completed within ~5 hours each
  - 5 grace days in total, at most 2 can be used for each assignment
  - Posted and submitted on Canvas.
  - Make Piazza posts if any questions!
- In-Class Midterm Exam: 10% [Oct 7]
- In-Class Final Exam: 15% [Dec 2]

Each unused grace day will be 0.4% bonus points added to the final grades!

— 1 letter-size cheat sheet allowed for both exams!

Online Platforms

- Announcements and Online Q&A: **Piazza**
  - https://piazza.com/cmu/fall2026/15369769
  - Access code: simulation
- Grades: **Canvas**
  - https://canvas.cmu.edu/courses/55420
- **Course website:** general info, lecture slides, resources
  - cs.cmu.edu/~15369-f26/

AI Tools Allowed With Proper Citation

- Mandatory Appendix for AI Tool Usage
- Citations and Academic Integrity
  - CMU's academic integrity policy
- Accuracy and Responsibility

Resources

- Textbook (not mandatory)
  - Solomon, J. (2015). Numerical algorithms: methods for computer vision, machine learning, and graphics.
- More graphics courses at CMU
- Physics Simulation in Visual Computing (with Javascript tutorial)
- Christopher Batty's physics-based animation site
- Open access to ACM SIGGRAPH-sponsored content
- Ke-Sen Huang's page on CG papers

Questions?

Image Sources

- https://www.theverge.com/2024/10/30/24283592/boston-dynamics-atlas-robot-autonomous
- https://www.3ds.com/make/solutions/industries/medical-3d-printing
- https://r-wong253249-sp.blogspot.com/2013/11/pose-to-pose-and-frame-by-frame-research.html
- https://dreamfarmstudios.com/blog/what-is-3d-rigging/
- https://www.physicsbasedanimation.com/