Numerical Methods

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Introduction

- Administration
- About me
- Course overview
Administration

- Course web
  http://caig.cs.nctu.edu.tw/course/NM

- Office hours
  - EC707, Wed 3:30—5:00 PM

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  - 劉政旻
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    - EC229B, ext. 56675
Textbook

References

Perquisites and Grading

- Perquisites
  - Calculus
  - Linear algebra

- Assignments (40%)
  - Written homework
  - MATLAB programming
  - Quiz (depending on class attendance)

- Midterm exam (30%)
- Final exam (30%)
Late and Cheating Policies

- Turn in assignments on the class of the due date
- Penalty of 10% of the value of the assignment/day
- 0 points for any cheating on assignments or test
About me

- Ph.D. in Robotics, School of CS, CMU
  - Texture synthesis, replacement and tracking
  - Physics-based animation
- M.S. & B.S. in Control Eng., NCTU
- Join NCTU in March 2006
Near-regular Texture Analysis and Manipulation

Near-Regular Texture Analysis and Manipulation

Yanxi Liu, Wen-Chieh Lin, and James Hays
Dynamic Near-regular Texture Tracking and Replacement

visibility map
Application: Superimposition with Occlusion
Dynamic Texture Replacement—underwater texture
Physics-based Animation
What is this course about?

- This is not a course to teach you to code.
- This is a course to teach you computer algorithms for analyzing and solving science and engineering problems in numerical ways.
Numerical Analysis/Methods

- What is numerical analysis/method?
  - Analysis and design of algorithms for numerically solving mathematical problems in science and engineering

- Why do we care about numerical analysis?
  - Simulation of real-world phenomena and events
  - Virtual prototyping of engineering designs
Analysis vs. Numerical Analysis

- Consider solving \( x^2 = 2 \)
- Analytically, we know that \( \sqrt{2} \) is a root of the equation
- Numerically, how do we find the root of the equation using a computer program?
- Computer can only do arithmetic operations
- Design a procedure consisting of only arithmetic operations to find the root
Numerically Solving

\[ x^2 = 2 \]

1.5^2 = 2.25 \hspace{1cm} \text{Too large}

1.4^2 = 1.96 \hspace{1cm} \text{Too small}

1.45^2 = 2.1025 \hspace{1cm} \text{A bit closer}

1.425^2 = 2.030625 \hspace{1cm} \text{Close}

1.4125^2 = 1.99515625 \hspace{1cm} \text{Pretty close}

This is actually a root finding method called “Bisection”!
Course Overview

- Approximation and errors
- Solving nonlinear equations

- Solving sets of equations
Course Overview (cont.)

- Interpolation and curve fitting
  - Find intermediate values from a table of data
  - Fit curves to data
  - If the curve passes all data points, we call it interpolation.
Course Overview (cont.)

- Approximation of functions
  - with polynomials or ratio of polynomials
- Numerical differentiation and integration
  - approximate derivative values of a function
  - approximate definite integral, even when no analytical form exists
- Numerical solution of ordinary differential equations
- Optimization
Applications of Numerical Methods

- Computer graphics—root finding, interpolation, curve fitting, optimization, ODE solver, PDE solver, finite element method
  - Physics-based animation
  - Geometry modeling
- Computer vision—optimization, curve fitting, linear equations
  - Stereo vision
  - Shape from shading
Applications of Numerical Methods (cont.)

- Machine learning—curve fitting, linear equations, function approximation
  - Pattern recognition
  - Neural network
- Simulation for prototyping—ODE solver, PDE solver, optimization, numerical integration, interpolation, finite element method
  - Circuit design
  - Mechanical design
  - CAD/CAM
Examples in Physics-based Animation

- Generate motion based on physical laws (e.g., Newton’s laws, Fluid dynamics)
- Simulated physical phenomena
  - gravity
  - momentum
  - collision
  - friction
  - fluid flow (liquid, gas, turbulence)
  - flexibility, elasticity
  - fracture
Simulated Flames

Duc Quang Nguyen, Ronald Fedkiw and Henrik Wann Jensen, SIGGRAPH 2003
Simulated Water

Nick Foster and Ronald Fedkiw, SIGGRAPH 2001
Simulated Cloth

Kwang-Jin Choi and Hyeong-Seok Ko, SIGGRAPH 2002
Simulated Deformable Object

Doug James & Dinesh Pai, SIGGRAPH 2002
Questions?