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SINGAPORE

CE7453: Numerical Algorithms

(AY2018/2019 S2)

Outline

§1. Organization information

§2. Course description

§3. Syllabus

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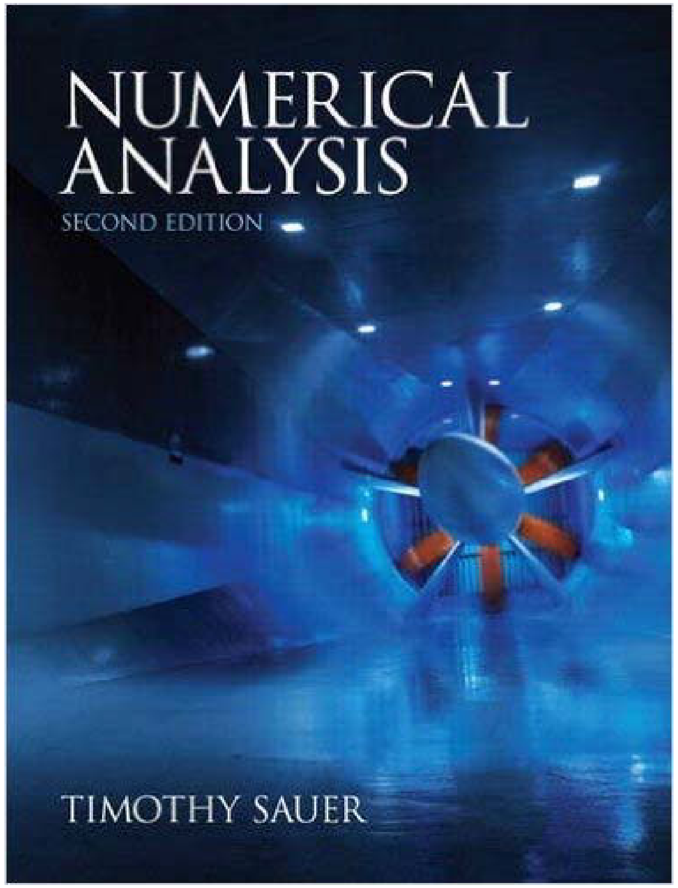
Course material

- Textbook: Numerical Analysis
- Course slides
- Course notes
- Complimentary research papers
- Your own notes



- Course homepage (→NTULearn)

  https://ntulearn.ntu.edu.sg/images/ci/NTUlearn/index.html

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Course components

- Lectures
- Exercises (Tutorials)
- Coursework (2 assignments)

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Organizational details

- Target students
  - Research students (PhD or M.Eng)
- Prerequisites
  - CZ1011 & CZ1012 or equivalent
- Where and when
  - LT13, Mon 2:30pm – 5:20pm
- How to pass
  - 50%: coursework (2 assignments)
  - 50%: final exam (written, 3 hours, closed-book)

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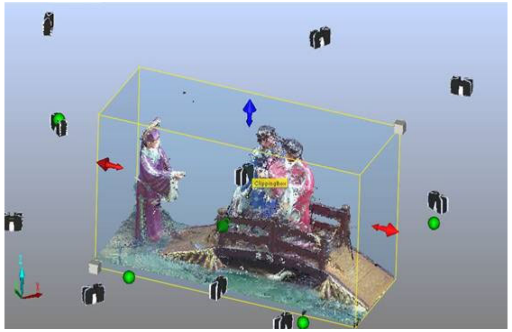
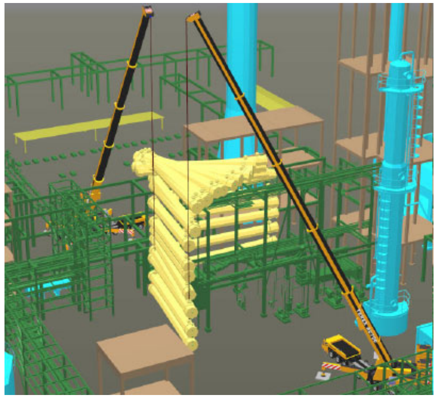
Background & motivation

- Many application problems are formulated into mathematical models, which are then solved ***numerically*** to find the solution.
  - E.g. 3D registration, TrueType fonts, GPS, motion planning, JPEG compression





- The success of solving the problems is closely related to how to design appropriate numerical algorithms.
  - It is quite often that some "*small*" or "*simple*" strategies make difference in applications.

A simple example

- Evaluate $P(x) = 2x^3 + 4x^2 - 5x + 3$
  - Method 1: 6 "*", 3 "+/-"

$$P(x) = 2 * x * x * x + 4 * x * x - 5 * x + 3$$

  - Method 2: 5 "*", 3 "+/-"

$$P(x) = 2 * x * (x^2) + 4 * x * (x) - 5 * x + 3$$

  - Method 3: 3 "*", 3 "+/-"

$$P(x) = [(2 * x + 4) * x - 5] * x + 3$$

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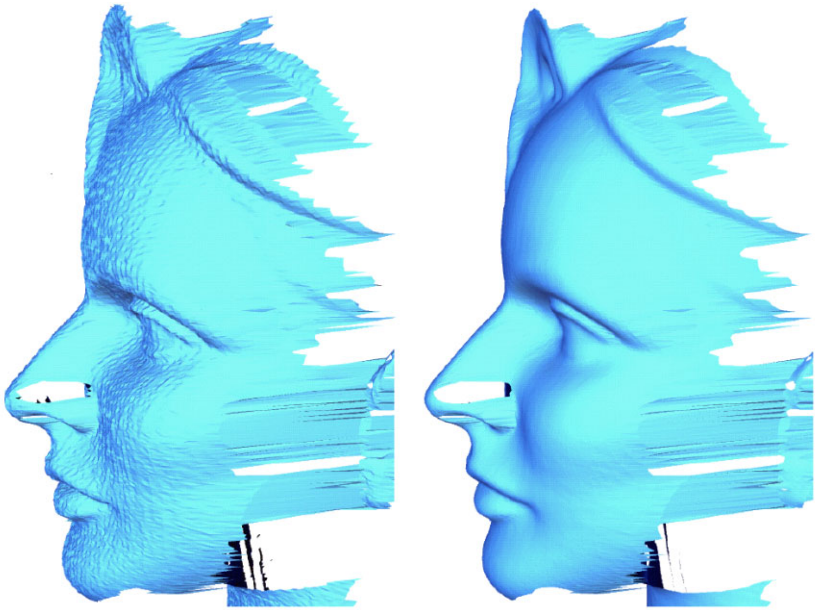
A CG example

- M.Desbrun, M.Meyer, P.Schroeder, A.Barr:

  "Implicit Fairing of Irregular Meshes using Diffusion and Curvature Flow"

  SIGGRAPH 1999. http://www.multires.caltech.edu/pubs/ImplicitFairing.pdf



Mesh fairing using diffusion process

$$\frac{\partial X}{\partial t} = \lambda L(X)$$

where λ is a diffusion parameter;

X is the set of vertices of a mesh;

L(X) is a Laplacian of X, which can be represented as a linear combination of X, i.e., LX.

A CG example (cont)

- Explicit Euler scheme:

$$\frac{X^{n+1} - X^n}{\Delta t} = \lambda L X^n \quad \Longrightarrow \quad X^{n+1} = (I + \lambda \Delta t L) X^n$$

- Implicit integration:

$$\frac{X^{n+1} - X^n}{\Delta t} = \lambda L X^{n+1} \quad \Longrightarrow \quad (I - \lambda \Delta t L) X^{n+1} = X^n$$

Original mesh

10 explicit integrations with $\lambda \Delta t = 1.$

1 implicit integration with $\lambda \Delta t = 10$.

The course is about

- key numerical algorithms that we should really want to know about
  - may provide clear answers to some real-world problems
- performance of the key numerical algorithms
- basic factors that should be considered when we design and analyze numerical algorithms
- some applications

Basic principles

- Convergence: whether and how the approximate solution converges to the correct one
- Complexity: a measure of the resources used in the algorithms
- Conditioning: sensitivity to error magnification
- Compression: realization of data in a shorter way
- Orthogonality: some ways to achieve efficiency & effectiveness

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Goals of the course

- To construct and explore algorithms for solving science and engineering problems
- To locate algorithms in a landscape of some potent & far-reaching principles

- To bring the basic mathematical concepts to life
- To learn how to leverage basic mathematics into great payoff in computing / engineering design and applications

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Features of the course

- Learning fundamental numerical algorithms
- Understanding basic mathematical background and skills behinds these algorithms
- Learning how to implement the methods and experience the practical aspects
- Exploring real-world problems as examples
- Emphasizing the insights of designing numerical algorithms

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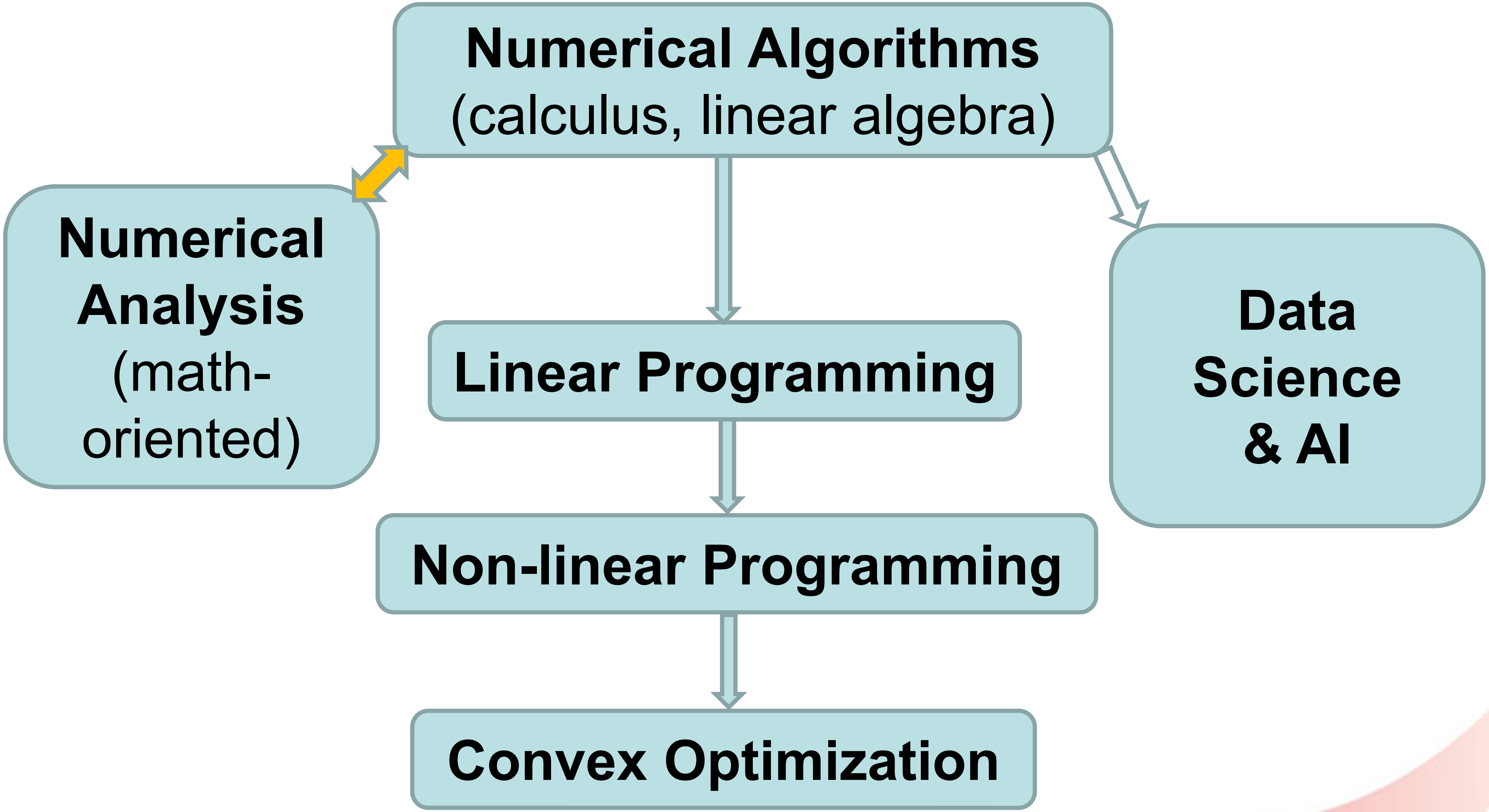
Relation with relevant subjects



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Outline

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Syllabus

- Newton's method
  - Root finding
- Linear systems
- Interpolation & approximation
  - Bezier curves
  - B-splines
  - TrueType fonts
- Differentiation and integration
  - Motion control

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Syllabus (cont)

- Least squares
  - GPS location estimation
- Eigenanalysis
  - Google's PageRank
- Case study: ICP for 3D data matching
- Fourier transformations
  - JPEG compression

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Tentative schedule

Week #	Time/Date	Topics
Week 1	14:30—17:20, Mon, 14 Jan 2019	Module 0: Introduction Module 1: Root Finding
Week 2	14:30—17:20, Mon, 21 Jan 2019	Module 2: Linear Systems
Week 3	14:30—17:20, Mon, 28 Jan 2019	Module 3: Bezier Techniques (TrueType Fonts)
Week 4	14:30—17:20, Mon, 04 Feb 2019	E-learning (eve of CNY)
Week 5	14:30—17:20, Mon, 11 Feb 2019	Module 4: B-spline Techniques
Week 6	14:30—17:20, Mon, 18 Feb 2019	Module 5: Interpolation
Week 7	14:30—17:20, Mon, 25 Feb 2019	Module 6: Differentiation and Integration (Motion Control)

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Tentative schedule (cont)

Week #	Time/Date	Topics
Week 8	14:30—17:20, Mon, 11 Mar 2019	Module 7: Least Squares
Week 9	14:30—17:20, Mon, 18 Mar 2019	Module 8: GPS location estimation
Week 10	14:30—17:20, Mon, 25 Mar 2019	Module 9: Eigenanalysis (Google PageRank)
Week 11	14:30—17:20, Mon, 01 Apr 2019	Module 10: 3D Data Matching
Week 12	14:30—17:20, Mon, 08 Apr 2019	Module 11: Fourier Transform
Week 13	14:30—17:20, Mon, 15 Apr 2019	Module 12: JPEG compression & Revision

End

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