THE UNIVERSITY OF TEXAS AT DALLAS

ERIK JONSSON SCHOOL OF
ENGINEERING & COMPUTER SCIENCE

COMPUTATIONAL SCIENCE & ENGINEERING

Notes prepared for EE 6481

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WHY A GRADUATE COURSE ON NUMERICAL METHODS?

- Numerical methods are "tools of the trade" in many areas of research and engineering design
  - ▷ Communication systems
    - ○ Wireless
    - ○ Optical
  - ▷ Plasma physics & plasma processing
  - ▷ Materials
  - ▷ Semiconductor devices and electronic circuits
  - ▷ Electromagnetics
  - ▷ Chemistry
  - ▷ Geophysics
  - ▷ Fluid dynamics, aerodynamics & aeronautical engineering
  - ▷ Civil & structural engineering
  - ▷ Signal processing

COMPUTATIONAL SCIENCE & ENGINEERING

- Traditional methods of analysis and design
  - ▷ Analytical
    - ○ Simple models for which a closed-form solution exists
  - ▷ Experimental
    - ○ Famous example: Invention of the telescope led to other discoveries
    - ○ U.S. engineering paradigm 70 years ago: Build and try
- Computation
  - ▷ A new method for analysis & design
    - ○ Complements, doesn't replace, analytical and experimental methods
  - ▷ More realistic models than analytical methods
  - ▷ Much larger parameter spaces than experimental methods
  - ▷ Reduces design costs and time to market
    - ○ Many failures can be detected and fixed before a system is prototyped

INGREDIENTS FOR SUCCESS IN COMPUTATION

- Mathematics
  - ▷ Linear algebra & linear systems theory
    - ○ Matrix computation
    - ○ Digital filters
    - ○ Stability analysis
  - ▷ Mathematical analysis (theory of convergence)
  - ▷ It's as important to know why numerical methods can fail as it is to know the limitations of an experimental instrument
- Computer architecture & performance analysis
  - ▷ Necessary for making efficient use of available resources
  - ▷ Higher efficiency $\Rightarrow$ larger maximum problem size
- Operating systems
- Programming languages

THE NUMERICAL APPROXIMATION

- Phrase due to Professor Willis Lamb
- Computational windowing
  - ▷ Restrict a real problem to a bounded region in space-time and a bounded set of function values
  - ▷ Computational boundaries and out-of-range values affect stability and accuracy of numerical algorithms
- Discretization
  - ▷ Reduce an infinite-dimensional problem to a finite-dimensional one by sampling, truncated expansion in a function basis, etc.
  - ▷ Introduces computational errors, artifacts, and noise