THE UNIVERSITY OF TEXAS AT AUSTIN

Fall 2024

EM 397, CSE 397: Nonlinear Static and Dynamic Finite Element Analysis (with particular emphasis on Solids, and a brief introduction to Isogeometric Analysis)

OFFICIAL SECTION NAMES:

CSE 397 2-NONLIN STAT/DYN FIN EL ANLY
Unique Number: 65095

EM 397 NONLIN STAT/DYN FIN ELEM ANLY
Unique Number: 14840

COURSE DESCRIPTION: Fundamental analytical technologies and code architectures used in nonlinear finite element analysis of solids and structures, including brief mention of isogeometric finite element analysis.

The course and office hours will be live in class. I have some travel this semester so I will record lectures when I am away. I do not like to travel when I teach but it is unavoidable this semester. Unfortunately, the first two lectures will be recorded.

INSTRUCTOR: Tom Hughes, hughes@oden.utexas.edu

CLASS SCHEDULE: Tuesdays and Thursdays, 2:00 pm – 3:30 pm.

OFFICE HOURS: Tuesday and Thursday, 3:30 pm – 5:30 pm (after class). I will reserve a conference room where we can meet. I will be available with some of my students to help with course material and your research questions. This course is to prepare you for and help you with your research into related subject matter.

WEB PAGE: https://canvas.utexas.edu

LEVEL: This is an advanced course aimed at graduate students in engineering, computer science, mathematics, and the physical sciences interested in developing new insights and skills that they may utilize in their research. The course also provides basic knowledge of procedures that are commonly used in commercial and industrial nonlinear finite element analysis programs.

TOPICAL OUTLINE (not necessarily in this order):

- Brief review of linear static and dynamic finite element analysis. This covers some material in the first three chapters of my FEA book (see below). If you have no background in functional analysis as it applies to FEA and would like to see a very introductory presentation, you might read Section 4.1.

- Some simple static nonlinear problems (partial differential equations and boundary conditions, weak/variational formulations, discretization by the Galerkin finite element method, and development of the matrix equations).

- Elementary solution algorithms for nonlinear algebraic problems (consistent linearization, Newton and modified Newton strategies, line search, and secant methods).

- Brief introduction to nonlinear continuum mechanics in the Lagrangian description.

- Formulation of large deformation problems, focusing on hyperelasticity (partial differential equations and boundary conditions, weak/variational formulations, discretization by the Galerkin finite element method, and development of the matrix equations).

- Code architecture for nonlinear finite element analysis of solids.

- Incompressible and slightly compressible media.

- Generalization to dynamics.

- Basic methods of time integration, such as Newmark and "alpha" methods.

- Isogeometric analysis as a generalization of classical finite element analysis.

- Introduction to computational plasticity. Return mapping algorithms. Operator splitting. Cutting plane and closest point projection.

- Phase field fracture analysis.

PREREQUISITES:

There are no formal prerequisites, but the course will require some mathematical maturity, including familiarity with ordinary and partial differential equations, a basic knowledge of finite element analysis, and an acquaintance with elementary

functional analysis concepts.

TEXT:

Notes will be provided.

RECOMMENDED BACKGROUND READING:

Hughes, T.J.R. (2000): *The Finite Element Method – Linear Static and Dynamic Finite Element Analysis*, Dover Publications, Mineola, New York.

Marsden, J.E. and Hughes, T.J.R. (1994): *The Mathematical Foundations of Elasticity,* Dover Publications, Mineola, New York.

Simo, J.C. and Hughes, T.J.R. (1998): *Computational Inelasticity*, Springer, New York, New York.

Cottrell, J.A., Hughes, T.J.R. and Bazilevs, Y. (2009): *Isogeometric Analysis: Toward Integration of CAD and FEA,* Wiley, Chichester, England.

Piegl, L. and Tiller, W. (1997): *The NURBS Book (Monographs in Visual Communication),* Springer-Verlag, Berlin, Heidelberg.

Akin, E., (2024): *Isogeometric Analysis for Engineers via MATLAB,* World Scientific, Singapore.

HOMEWORK POLICY:

There will be frequent assignments. Homework will be due at the end of the class on the due date. The homework will be graded.

TESTING AND EXAMINATION PLAN AND POLICIES:

There will be no tests or exams.

GRADING POLICY:

Grades will be based on the homework.

CLASS FORMAT:

Lectures.

ATTENDANCE:

Attendance at lectures is expected.

EVALUATION:

The course and instructor will be evaluated at the end of the semester using the approved procedures.

COMPUTER:

Some homework assignments will involve computing.

You may also find it necessary to use **Matlab** for some assignments. You may buy the student version of **Matlab** to use on your own computer at the Campus Computer Store or you can obtain it from the MathWorks website: http://www.mathworks.com

There are many open-source programs available that include finite element and isogeometric capabilities. I do not plan to use a particular one. You may choose whichever one you like as the need arises. **Matlab** has elementary FEA capabilities and the IGA book by Ed Akin utilizes **Matlab.**

The FEA program that accompanies my FEA book is called **DLEARN**. It is written in Fortran. I thought it might be interesting to use AI to convert it to a few of the preferred computer languages of students in the class and see if that works.

DROPPING COURSES:

Information for graduate students concerning different kinds of drops and deadlines may be found at

https://gradschool.utexas.edu/academics/policies/adding-and-dropping-courses

SPECIAL NOTES:

The University of Texas at Austin provides upon request appropriate academic adjustments for qualified students with disabilities. For more information, contact Services for Students with Disabilities:

512-471-6259
Email: access@austin.utexas.edu
Schedule: Drop In/Office Hours