Learning Outcomes

Overall course learning outcome
By the end of this course, students will be able to design and execute computer programming solutions to civil engineering problems using numerical methods.

To achieve this goal, students will learn to:

- Translate numerical methods into simple, reusable program modules
- Choose appropriate numerical methods for solutions to specific mathematical problems
- Analyze the applicability and accuracy of numerical solutions to specific mathematical problems
- Synthesize multiple program modules into larger program packages
- Distill numerical results into a readable format that answers specific civil engineering analysis and design questions

Course Modules
This course is organized into five course modules. The following list summarizes these categories and provides the specific content and learning outcomes for each module.

Module 1: Basic Structured Programming (Lectures 1-7)
The first part of this course will introduce the basic building blocks of structured computer programs. These include the following topics:

1. Variables and data types
2. Logical operations
3. The basic control structures IF, FOR, and WHILE
4. Programs and user-defined functions
5. Variable passing and computer memory
6. Debugging techniques

Once the material in this module is mastered, students will be able to:

- Use variables, operators, and control structures to implement simple sequential algorithms
- Use Matlab m-files to create user-defined programs and functions
- Develop simple logical algorithms to solve engineering problems
- Generalize program code to create modules that encapsulate reusable parts of an algorithm
- Test program output for accuracy using hand calculations and debugging techniques
- Synthesize multiple program modules (including built-in Matlab functions) into larger program packages
Module 2: Introduction to Numerical Methods (Lectures 8-10)

Most of the programs created in this course will implement numerical solutions to civil engineering problems. In this section we introduce the basic notation for interpreting numerical methods through illustration by the following topics:

1. Taylor series expansion
2. Error measures
3. Root-finding techniques

Though brief, by the end of this module, students will be able to:

- Translate numerical methods into simple, reusable program modules
- Choose appropriate numerical methods for solutions to specific mathematical problems
- Analyze the accuracy of numerical solutions to specific mathematical problems

Module 3: Arrays and Matrices (Lectures 11-14)

Most numerical methods require holding multiple, related values in a single array for bookkeeping purposes or utilize matrices to find the solution to systems of simultaneous equations. This section introduces arrays and matrices through the following topics:

1. The Matlab array data type
2. Basics of linear algebra
3. Naïve Gauss elimination
4. Gauss elimination with pivoting
5. The matrix inverse
6. Issues of numerical stability

By the end of this module, students will be able to:

- Store and manipulate datasets in Matlab arrays
- Write systems of equations in matrix form
- Manipulate equations following the rules of matrix algebra
- Write simple program modules to implement matrix operations
- Analyze the applicability and accuracy of matrix numerical solutions to linear systems of equations
- Calculate solutions to civil engineering problems using matrix algebra

Module 4: Data Modeling (Lectures 15-18)

One reason computers are so vital to civil engineering practice is the vast amount of data engineers are often required to process. This module will introduce several standard methods to describe and model data, including:

1. Regression
2. Interpolation
3. Extrapolation
4. Statistics
5. Measures of goodness-of-fit

Once the material in this module is mastered, students will be able to:
• Apply standard modeling techniques to describe and summarize large datasets
• Calculate results from data analysis using regression, interpolation, and extrapolation
• Analyze the quality of a particular model designed to represent a given data set
• Distill discrete data values into a readable format that answers specific civil engineering analysis and design questions

Module 5: Numerical Modeling and Simulation (Lectures 19-28)

Computers are widely used to simulate the behavior of complex systems using numerical solutions to differential equations. This module will introduce basic numerical methods for integration, differentiation, and solutions to differential equations. The topics covered include:

1. Integration
2. Differentiation
3. Initial value problems
4. Boundary value problems
5. Eigenvalues
6. Partial differential equations

This module somewhat synthesizes each of the prior modules of the course. By the end of this section, students will be able to:

• Implement algorithms to perform numerical differentiation and integration on a discrete numerical grid
• Apply numerical solutions to differential equations to build numerical models of civil engineering systems
• Analyze the applicability and accuracy of numerical solutions to differential equations
• Distill numerical results into a readable format that answers specific civil engineering analysis and design questions