CVEN 302-502
Computer Applications in Engineering and Construction

Learning Outcomes

Overall course learning outcome

By the end of this course, students will be able to design and implement computer programs consisting of multiple modules of numerical methods to analyze civil engineering problems.

To achieve this goal, students will learn to

- Write simple program modules to implement single numerical methods and algorithms
- Calculate solutions to civil engineering problems using standard numerical methods
- Test program output for accuracy using hand calculations and debugging techniques
- Analyze the applicability and accuracy of numerical solutions to diverse civil engineering 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 nine course modules. The following list summarizes these categories and provides the specific content and learning outcomes for each module.

Module 1: Introduction to Matlab Programming (Lectures 1-6)

The first part of this course will introduce the smallest building blocks of computer programs. These include the following topics:

1. Variables and data types
2. Assignment statements
3. Logical operations
4. The basic control structures IF, FOR, and WHILE

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
- Generalize program code to create modules by moving problem-specific information to the header of a program

Module 2: Program Design and Testing (Lectures 7-10)

Once the building blocks of computer programs are understood, this section of the course will present how to assemble a program from multiple program modules. The topics of this section include:

1. Iteration and arrays
2. User-defined functions
3. Variable passing and computer memory
4. Debugging techniques

After completion of this module, students will be able to:

- Write simple program modules to implement single logical algorithms
- Test program output for accuracy using hand calculations and debugging techniques
- Synthesize multiple program modules into larger program packages

Module 3: Introduction to Numerical Methods (Lectures 11-15)

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
2. Error measures
3. Root-finding techniques

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

- Write simple program modules to implement single numerical methods and algorithms
- Calculate solutions to civil engineering problems using standard numerical methods
- Analyze the accuracy of numerical solutions to diverse civil engineering problems

Module 4: Arrays and Matrices (Lectures 16-21)

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

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

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

- 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 5: Data Modeling (Lectures 22-27)

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 and 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 6: Numerical Calculus (Lectures 28-30)

Computers are also vital for obtaining approximate numerical solutions to calculus operations that have no known analytical solutions. This module will introduce numerical methods for the two basic building blocks of calculus:

1. Differentiation
2. Integration

From the material in this section, students will be able to:

- Write simple program modules to perform numerical differentiation and integration on a discrete numerical grid
- Analyze the accuracy of numerical approximations to derivatives and integrals and their dependence on grid resolution

Module 7: Numerical Modeling and Simulation (Lectures 31-42)

Finally, computers are widely used to simulate the behavior of complex systems using numerical solutions to differential equations. This section will address the following topics

1. Initial value problems
2. Boundary value problems
3. Eigenvalues
4. Numerical stability and accuracy
5. 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:

- 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