Computational Science Program for Ohio Community and Technical Colleges

Draft Competencies for Introduction to Computational Methods
March 2008

Competency/Descriptors
Conduct various tests of significance to determine if observed differences are attributed to actual changes in underlying processes or simply chance: **Descriptors:** Create a probability table for each possible random event associated with the process phenomena under consideration. Formulate both null and alternate hypotheses. Utilize the Chi Square and other appropriate statistical tests to test various hypotheses regarding population differences or differences in samples Example: Use the Chi Square test to determine significant numerical deviations associated with the expected number of heads for multiple tosses of fair coins.
Analyze the accuracy and precision of empirical data: **Descriptors:** Explain the reason for natural variation of measurements. Propagate measurement errors and determine how they impact the results of empirical data. Assess and measure probabilities. Calculate the mean, median and standard deviation of a data set. Conduct simple statistical tests to assess sample information against known population information. Example: Test a sample mean against a hypothesized population mean
Conduct basic mathematical operations used in the application and study of science (reinforce and review concepts from Introduction to Modeling and Simulation course): **Descriptors:** Represent numbers in scientific notation. Convert numbers between standard notation and scientific notation. Convert the units of numbers between the three basic systems of measurement, CGS, MKS and English. Organize scientific information into tables and graphs. Produce graphs with grids, axis labels, titles, legends, error bars, fitting functions, and correct units. Determine and propagate errors associated with measurement, truncation, round off etc. Utilize a variety of graphs, 2D, histograms, pie, bar, 3D, contour, carpet plots, etc. Example:
Analyze empirical data to determine the mathematical representation that most accurately

represents the data (reinforce and review concepts from Introduction to Modeling and Simulation course):

Descriptors:

Describe linear functions.
Define non-linear functions; polynomial, exponential, logarithmic, trigonometric, parameterized, etc.)
Determine the appropriate functional form to fit empirical data.
Generate and interpret descriptive statistical parameters for an empirical data set.
Visualize empirical data and fitting functions utilizing software (e.g. Excel, Matlab, Maple, Mathematica, Vensim, etc.)

Example: Collect empirical data, develop a mathematical representation for the data, make predictions and test them, e.g., calibrate a servo motor and the Sam robot or determine the amount of rain flowing through a drain pipe during a rain storm.

Develop a first order differential equation system model and transform it to difference equations:

Descriptors:

Analyze unconstrained and constrained systems of growth and decay.
Conduct a project based study of a first order differential equation model.
Explain how initial conditions and growth/decay rates impact the results.
Analyze the impacts of constrains on the growth and/or decay of a system.

Example: Develop a mathematical representation for a predator-prey system and derive the difference equation from it.

Develop a second order differential equation system model and transform it to difference equations:

Descriptors:

Analyze dynamics systems represented by second order differential equations.
Transform the second order differential equations modeling a dynamic system into difference equations.
Analyze the range of validity of the difference equations.
Describe modeling problems with higher order difference equations analyze their solution methodology.
Analyze the long-term behavior.

Example: Model a bungee jumper or a falling skydiver and transform the mathematical representation to difference equations.

Develop a system dynamics model involving interactions:

Descriptors:

Identify the interactions in a community and model the competitive relationships among the participants.
Develop a mathematical representation of the competitive interactions.
Transform the mathematical representation into a computational model.
Conduct a study using the competitive model.

Example: Model the interference competition of titmice versus other birds at feeders.

Analyze methods for solving non-linear equations

Descriptors:

Discuss and contrast fixed point methods (e.g., bisection, secant, Newton's) for a single equation
Describe a fixed point method for a system of equations (e.g., Newton's)

Example:

Describe techniques for solving systems of linear equations

Descriptors:

Describe the naïve Gauss elimination and the partial pivoting method
Understand the concepts of condition number and ill-conditioning problems
Discuss and contrast factorization methods (e.g., LU, QR, Cholesky, SVD)
Discuss and contrast iterative methods (e.g., Jacobi, Gauss Siedel)
Describe convergence and stopping criteria of iterative methods

Example:

Describe interpolation and approximation methods

Descriptors:

Describe and contrast interpolation methods.
Describe interpolation with spline functions (e.g., piecewise linear, quadratic, natural cubic)
Discuss approximation using the method of least squares (linear .vs. non-linear)

Examples:

Describe numerical methods for Ordinary Differential Equations

Descriptors:

Describe and compare basic methods for IVPs (e.g., Euler, Taylor, Runge-Kutta)
Describe and compare predictor-corrector methods
Describe and compare multistep methods
Discuss and contrast numerical methods for BVPs (e.g., shooting method, finite difference method)
Compare the accuracy, memory requirements, and precision of each of the approaches

Examples:

Describe Monte Carlo Methods and their application:

Descriptors:

Describe applications of Monte Carlo models
Discuss algorithms for Monte Carlo methods
Define a random walk simulator, e.g., chain reactions, diffusion
Use a Monte Carlo simulation to generate an output distribution for a given distribution

Example: Calculate the area/volume of an irregular shaped object.