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Water Resource Systems Analysis - University of Kentucky, Lexington

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CE665
WATER RESOURCE SYSTEMS ANALYSIS

INSTRUCTOR

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COURSE DESCRIPTION

Application of systems analysis, mathematical modeling, numerical analysis, and optimization in water resources planning, design, construction, management and operation. Solution of engineering problems found in water supply, water and wastewater treatment, urban drainage, and river basin development and management by use of linear, nonlinear, and dynamic programming models.

COURSE OBJECTIVES

1. To provide the student with a basic overview of systems analysis along with a discussion of various water resource systems.
2. To provide the student with a basic overview of knowledge engineering and current methods for use for stakeholder engagement
3. To provide the student with a basic overview of the concepts of mathematical modeling including the construction and application of both inductive and deductive computer models.
4. To provide the student with a basic overview of economic analysis as applied to water resource systems.
5. To provide the student with a basic overview of inductive models for water resource systems, including numerical methods for model applications.
6. To provide the student with a basic introduction to the use of stochastic methods in water resources including water demand and streamflow forecasting.
7. To provide the student with a basic overview of deductive models for water resource systems, including numerical methods for model applications.
8. To provide the student with a basic overview of prescriptive models for water resource systems, including both analytical and numerical numerical methods for solution.

GRADING

The grade for the course will be based on the following distribution:

Homework 30%
Quizzes 40%
Term Project 20%
Project Presentation 10%
The university grade system as defined in the general school catalog will be applied to determine the corresponding letter grade.

**HOMEWORK**

Homework assignments will be made regularly throughout the semester. Late homework may be turned in for evaluation but will not be counted toward the final grade unless accompanied by a university approved excuse.

**TERM PROJECT**

Each student will be required to apply a particular optimization method to a selected water resources/environmental system, prepare a report, and make an oral class presentation.

**TEXTBOOKS/CLASS NOTES**

Class lectures will be drawn from the following textbooks as well as from class handouts.


**BIBLIOGRAPHIES**

Much of the material that we will be covering in the class, has not made it yet into textbooks. As a result, an extensive bibliography of relevant journal articles and reports is provided in support of the topics to be covered.

**SOFTWARE**

www.ece.northwestern.edu/OTC/

www.lindo.com

www.solver.com

www.iseesystems.com/
CE699 General Guidelines for Homework

1. General format for each problem should include:
   a. problem statement
   b. methodology
   c. results
   d. discussion
   e. summary/conclusions

2. Provide a printed layout of any spreadsheets used, including descriptions of all rows and columns.

3. Be sure to provide written descriptions of variables/equations.

4. All tables and figures should be labeled and referenced in descriptive text.

5. Figures should be labeled at the bottom. Tables should be labeled at top.

6. Figures and Tables should be oriented top to bottom or left margin to right margin.

7. All items in tables and figures should have appropriate and identified units.

8. All data sources should be referenced (including those from web).

CE699 Report Contents

1. Introduction
2. Problem Statement
3. Mathematical Formulation of Problem
4. Discussion of Numerical/Optimization Methods Used
5. Discussion of Analysis
6. Presentation of Results
7. Discussion of Results
8. Discussion of Results
9. Conclusions/Recommendations

CE699 Report Format Guidelines

All reports should be written consistent with the Report Writing Style Guide for Engineering Students by Anne Winckel and Bonnie Hart with the University of South Australia (see dropbox).

Dropbox

Class assignments, lecture notes, models, and supporting publications will be provided in a class dropbox for access by members of the class. Each student is responsible for downloading and keeping up with the associated assignments.
CE 699 COURSE OUTLINE

1. Introduction to Water Resources Engineering ([1], Handouts)

2. Introduction to the System Approach ([2], Handouts)

3. Knowledge Engineering (Handouts)
   A. Stakeholder Engagement
      1) Community Based Participatory Communication
      2) Structured Public Involvement
      3) Casewise Visual Evaluation
   B. Collaborative Modeling
   C. Expert Systems

4. Introduction to Water Resource Modeling (Handouts)
   A. Conceptual Models
   B. Mathematical Models
      1) Model Formulation
         1) Inductive Models
         2) Deductive Models
            a) Deterministic Models
            b) Empirical Models
      2) Model Construction
      3) Model Verification
      4) Model Calibration
      5) Model Validation
      6) Model Application
   C. Modeling Challenges
   D. Model Selection
   E. Model Case Studies
Bibliography on Stakeholder Engagement


U.S. DOE, An Evaluation of DOE-EM Public Participation Programs, February 2003


Bibliography of Community Based Participatory Communication


Bibliography of Structured Public Involvement


**Bibliography of Casewise Visual Evaluation**


**Bibliography of Collaborative Modeling**


Bibliography of Knowledge Engineering Applications


Water Expert: http://expert.ei.ua.edu/

Examples of Model Calibration


5. Economic Models [1]
   A. Concept of Interest/Rates
   B. Cash Flow Diagrams
   C. Economic Analysis
   D. Project Analysis
   E. Market Economics
   F. Welfare Economics

6. Introduction to Prescriptive Models [2, 3, 4]
   A. Optimality Conditions
   B. Univariate Optimization
      1) Newton’s Method
      2) Secant Method
      3) False Position Method
      4) Bisection Method
      5) Polynomial Interpolation
      6) Golden Section Method
   C. Analytical Methods for Unconstrained Optimization
      1) Newton’s Method
      2) Steepest Descent Method
      3) Conjugate Gradient Method
      4) Davidon Fletcher Powell Method
   D. Analytical Methods for Constrained Optimization
      1) Substitution Method
      2) Lagrange Multiplier Method

Quiz 1
7. Numerical Methods for Inductive Models [1], [Handouts]

A. Deterministic Models

1) Interpolation Analysis
   a) Reservoir design application
   b) Manning’s equation approximation

2) Regression Analysis
   a) Demand forecasting application

3) Neural Network Analysis
   a) Watershed model application

4) GP/GA Function Analysis
   a) Stream water quality application

B. Stochastic Models [1], [Handouts]

1) Probability Theory
   a) Pathogen modeling application

2) Frequency Analysis
   a) Flood prediction application

3) Hypothesis Testing
   a) Stream Water Quality

3) Time Series Analysis
   a) Demand forecasting application
   b) Streamflow forecasting application

Quiz 2
Applications of Inductive Models


8. Numerical Methods for Deductive Models [1],[3], [Handouts]

A. Deterministic Models

1) Numerical Solution of Nonlinear Equations
   a) Normal depth application
   b) Green Ampt equation
   c) Nonlinear reservoir runoff application
   d) Pipeline design
2) Numerical Integration
   a) Stream area application
   b) Hydrograph volume application
3) Numerical Solution of Differential Equations
   a) Draining Tank
   b) Reservoir routing application
4) Numerical Solution of Partial Differential Equations
   a) Groundwater modeling application
   b) Flood routing applications
5) Systems of Linear Equations
   a) Hydrograph translation application
   b) Reactor Application
6) Numerical Solution of Nonlinear Sets of Equations
   a) Water distribution application
      1) Steady state analysis
      2) Transient analysis
      3) Water Quality analysis

Quiz 3
Applications of Deterministic Models


9. Numerical Methods for Optimization Analysis [1], [2], [3], [Handouts]

A. Optimality conditions

B. Unconstrained Optimization
   1) Pattern Search Methods
      a. Simplex Method
      b. Hooke Jeeves Method
      c. Fletcher Powell Patterned Search
   2) Evolutionary Methods
      a. Genetic Optimization
      b. Ant Colony Method
      c. Particle Swarm Method

C. Constrained Methods
   1) Generalized reduced gradient method
   2) Penalty function methods
   3) Box complex method
      a. Detention basin design
      b. Hydraulic network model calibration
      c. Hydraulic network design
      d. Optimal pump scheduling
      e. Activated sludge design

D. Linear Programming
   1) Problem Formulation
   2) Solution Methods
      a. Graphical
      b. Sequential Equation
      c. Matrix methods
         1) Simplex Algorithm
         2) Revised Simplex Algorithm
      d. Applications
         1) Regional wastewater
         2) Hydraulic network design
         3) Reliability design
         4) Reservoir operation

E. Integer/Mixed Integer Programming
   1) Branch and Bound Algorithm
   2) Applications
      a. Coverage problem
      b. Production problem

F. Dynamic Programming
1) Pipeline design  
2) Reservoir operation  
3) Detention basin design  

G. Stochastic Programming  
1) Stochastic DPs  
2) Chance constrained LPs  

Quiz 4  

Applications of Optimization Models  


