Simulation Modeling in the Performance Evaluation and Optimal Design of Aquatic Ecosystems

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The Problem Statement

• Given a network of water masses
  – E.g. the Finger Lakes, Great Lakes
• Optimize some performance measure
  – Preservation of the wetlands
• Subject to a set of economic, social, political, environmental, climatic, etc. problem constraints
  – Maintaining levels of employment, health
Example: River Port w/Lagoon

Figure 1: Schematic of the River Port and Lagoon aquatic ecosystem.
• Controlled Variables: Economic
  • * EcoSite Replenishing Levels (MIN)
  • * EcoSite Capacities (MAX)
  • * EcoSite Ordering Schedule
    • * Water Transfer Policy
    • * Water Usage Policy
    • * Water Shortage Policy
    • * Water Table Level
  • * EcoSite Initial Conditions
• Controlled Variables: Ecologic
  • * Wetland size
  • * Water Temp
  • * Transfer Speed
  • * Water Salinity
    • * Pollution
    • * Area/Depth
  • * Fish/Foul Population
  • * Fish/Foul Reproduction
Some Applications

- Design and optimization of ecosystems
- Study of hazard impacts on ecosystem
- Arbitration and Conflict Resolution
- Citizen and public education
- Ecological education
- Statistical education
- Simulation and education
Methods of Resolution

• Theoretical (law or relation)
  – But, can we come up with the equation?

• Empirical (regression)
  – But, can we find enough data?
  – Its functional form is arbitrary

• Discrete Event Simulation
  – Don’t need to relax the assumptions
  – Can include complex interactions
Simulation Data Sources

- Hydrological data bases
- Census data
- Chamber of Commerce
- Agrarian unions and organizations
- Industrial organizations
- Other ecological studies
Steps in Model Building

• Define model objectives and scope
• Define performance measures
• Define Factors, levels, interactions
• Define relationships among components
• Define Data Bases for parameter estimation.
• Estimate parameters and distributions
• Define data for model validation
• Conceptual model evaluation
Simulation Analysis Steps

- Simulation Model Programming
- Model Verification and Validation
- Design of Experiments
- Production Runs
- Statistical Data Analysis and Results
- Validation of Statistical Assumptions
- Conclusions, Modifications, Restart
Simulation Results Example

Figure 2: Complete Factorial Experiment for the Simulation

River Port Capacity

Water Transfer Policy

Seasonality

Response: Total Cost

Rain

Dry

A/2

A/3

Two

581

502

580

636

1096

688

744

One

Two

680
Additional Advantage

Multi-criteria (ecological, social, economic, etc.) system responses (from the elements in Table 1) can be obtained, by combining (say k) contrasting and competing individual responses (say j) into a single, complex one. The linear combinations formed (i) quantify the contrasting policies and philosophies of different constituencies. This way, comparisons of competing and contrasting policies, produced by the simulation model results, can provide an environment where diverse constituencies can rationally discuss their differences and better reach a consensus.
A Version of this Work

- Was Presented to the 2003 FCSM
- Federal Conference on Statistical Methods
- It is on the Internet at:
- Some literature background is given
  - In the next and final slide.
Romeu, J. L. "Simulation and Statistical Education". Proceedings of the 1995 WSC.