Dynamic Systems, Neural Networks

Picker Engineering Program
Smith College
EGR 301

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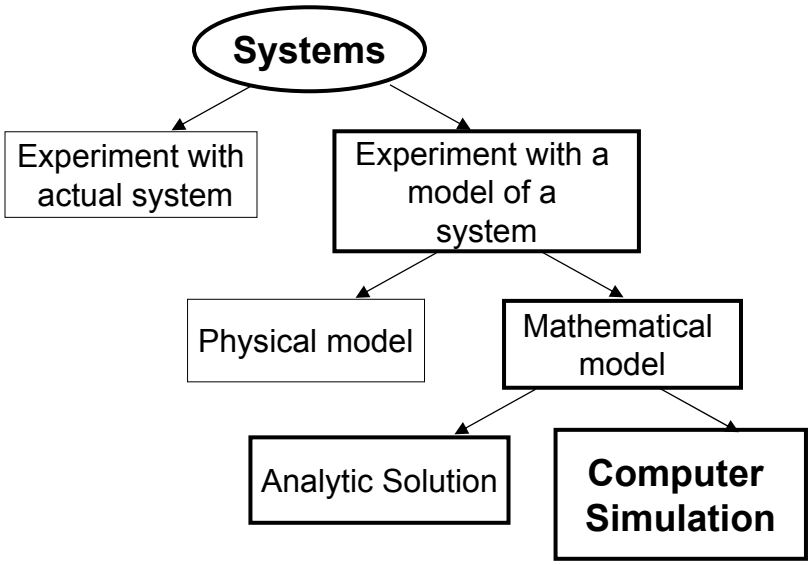
Overview

- Course administration
- The purpose of modeling & simulation
- What is a dynamic system?
  - Policy: Aid to developing countries
  - Engineering: Electric power system
- How are neural networks and dynamic systems studies related?
- Pendulum man

Modeling and Simulation

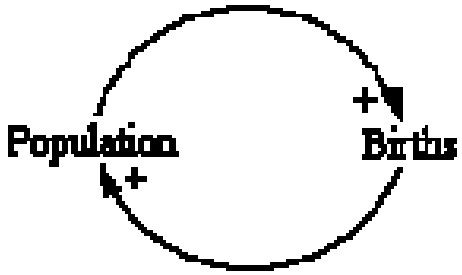


Systems to Model & Simulate

- Dynamic system
  - System
    - A combination of interacting elements
    - …that act together to perform a specific objective
  - Dynamic
    - Systems or phenomena that produce time-changing patterns
    - ... that evolve or change with time
- Policy analysis
- Engineering analysis

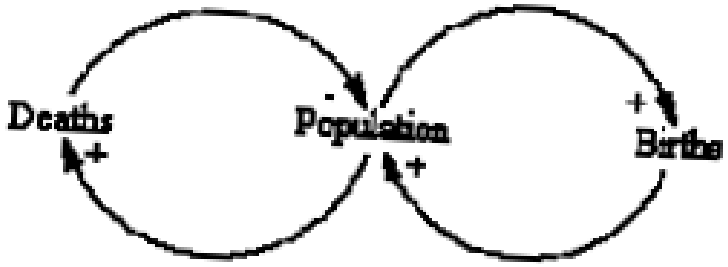
Policy: Causal Loop Diagram

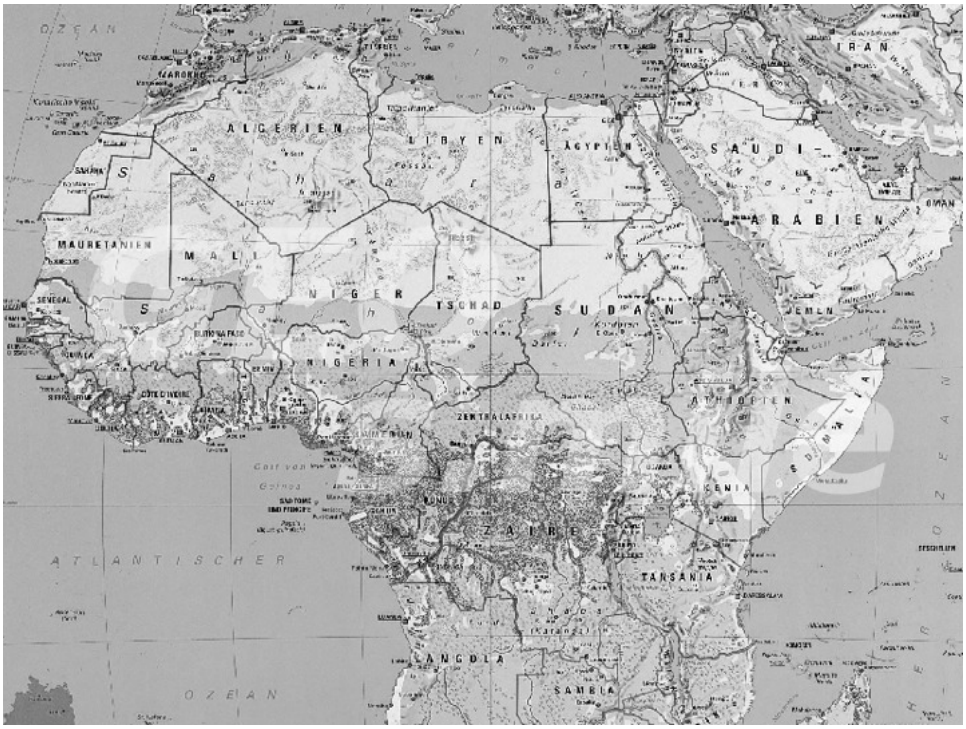
- A method for diagramming and understanding relationships between system elements, especially feedback
- Positive feedback shown below



Policy: Causal Loop Diagram

- Additional dynamics (relationships and time evolution)
  - Population ↑ leads to death ↑
  - Death ↑ leads to population ↓





The Tragedy of the Sahel

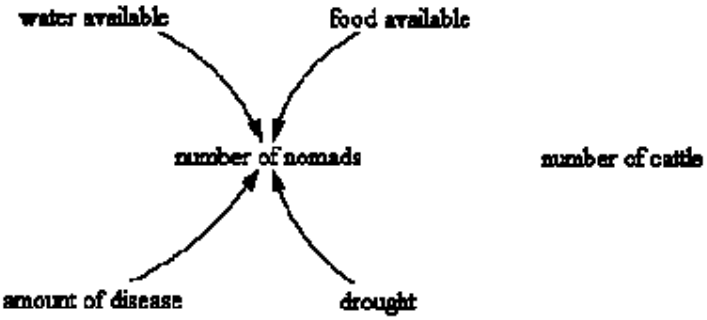
- Narrow strip of land south of the Sahara desert
- Limited resources have limited the size of both nomad and grazing animal populations
  - Every 20-30 years drought killed many
  - Populations maintained at viable levels
- Nomad survival system
  - Depended upon moving grazing animals often
- In the 1960s aid organizations tried to help the nomad population
- Steps taken by organizations
  - Introduce modern medicine
    - Greatly increased nomad lifespan
    - Controlled animal diseases
  - Increase availability of water with modern technology
    - Increased the number of animals the nomads could own

The Tragedy of the Sahel

- A list of important system elements
  - Nomad population
  - Animal population
    - Small populations
  - Limited food
  - Limited water
  - Limited herds
  - Severe climate
    - Severe drought
  - Disease
  - Poor diets

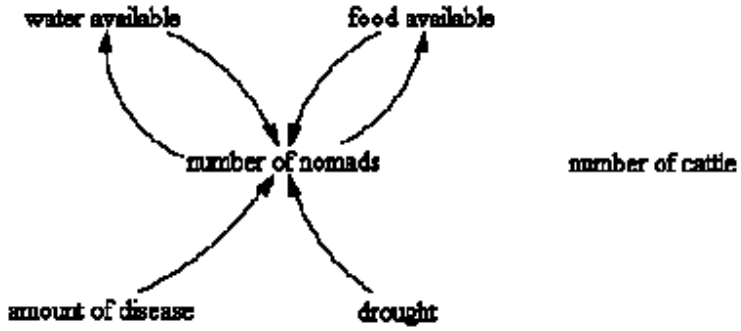
Modeling the Tragedy of the Sahel

- The number of nomads and the number of cattle interact with almost every other element
- Arrows show which elements affect the number of nomads



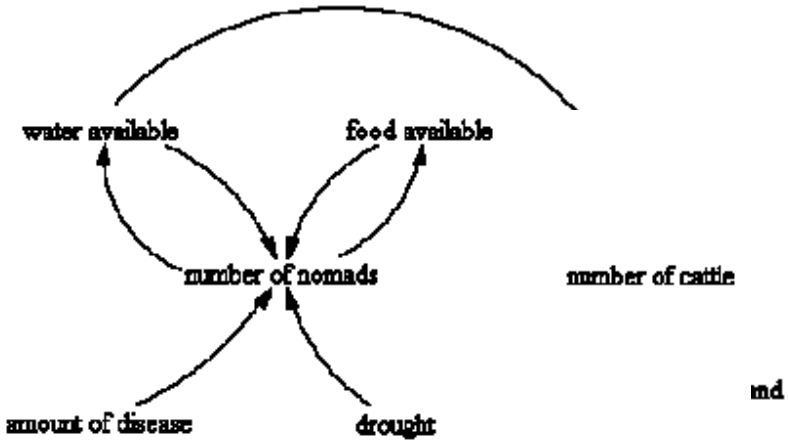
The Tragedy of the Sahel

- Arrows show which elements are affected by the number of nomads



The Tragedy of the Sahel

- Arrows to show everything that affects and is affected by the number of cattle



The Tragedy of the Sahel

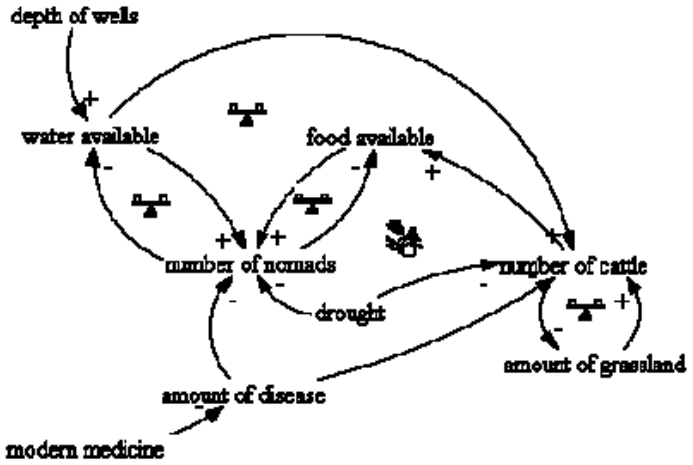
- Results of intervention
  - → Animals died of starvation
  - → Nomads died of starvation
  - – The increased animal population ate and trampled the little grass that had been available
  - – A cyclic drought further decimated grass
- *Unanticipated result!!*
- The UN was faced with a problem larger than the one they initially tried to 'solve'

The Tragedy of the Sahel

- A list of important system elements
  - – Nomad population
  - – Animal population
    - Small populations
  - – Limited food
  - – Limited water
  - – Limited herds
  - – Severe climate
    - Severe drought
  - – Disease
  - – Poor diets
  - – Modern medicine
  - – Deeper wells
  - – Increased number of animals
  - – Limited grasslands
    - Eaten
    - Trampled
  - – Animals starved
  - – People starved

The Tragedy of the Sahel

- Outside intervention added
- (+) (–) feedback signs added



The Tragedy of the Sahel

- What happened?!
  - Adding the 'positive' input of water counteracted the 'negative' feedback of water ↓ as nomad population ↑
  - Intervention removed the negative feedback that previously maintained the system
- Introducing medicine and water together allowed both populations to grow larger than the ecosystem could support

Modeling Systems

- Use of causal loop diagrams
  - Constructing a diagram is straightforward
  - Understanding the dynamics in a diagram is more difficult
- System behavior can only be understood with the use of quantitative (mathematical) simulation models
  - The behavior of a system cannot be determined from such a diagram

Blackouts

"All the News That's Fit to Print"

The New York Times

New England Edition
Boston: Mostly sunny, hot. High 87, cooler at coast. Tonight, mainly clear, mild. Low 72. Tomorrow, partly sunny, humid, scattered thunderstorms. High 87. Weather map is on Page C18.

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POWER SURGE BLACKS OUT NORTHEAST, HITTING CITIES IN CANADA AND 8 STATES; MIDDAY SHUTDOWNS DISRUPT MILLIONS

Power System Variables

- **Input data:**

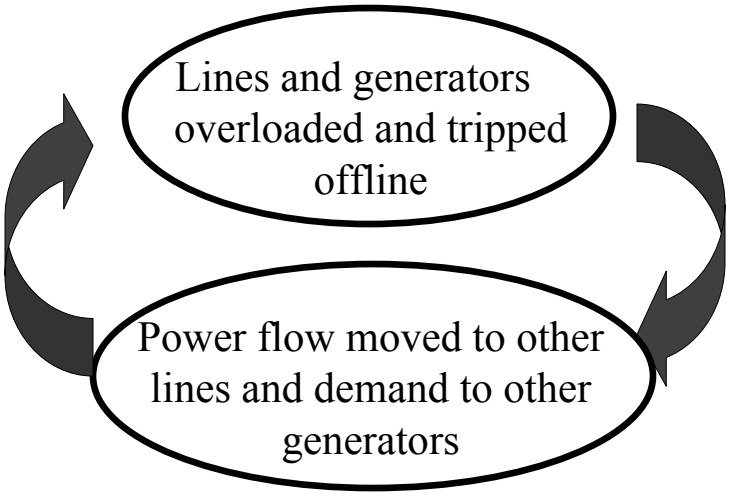
  Generators produce, and we consume, *two* commodities
  - Real power, **P**
    - useful work
  - Reactive power, **Q** - system EM support

- **Output (measured) data**
  - *Single* system-wide frequency, f (60Hz)
  - Voltage levels specified for each location

Operating the Power System

- All values of interest evolve over time – they are dynamic, and they are inter-related (coupled)
  - Power generation and consumption (load) Power flows change with load changes and with equipment failure
  - Frequency is maintained close to 60Hz
  - Voltage is maintained close to its "set point"

What Happened in August 2003?



What Happened in August 2003?

- Problems in southern Ohio distracted operators
- Computers for monitoring the power system down in northern Ohio and at Midwest system operator
- Insufficient reactive power (voltage support) in northern Ohio
  - Suspicions that new market conditions (restructuring) led to this result

Power System Modeling

- Obtain or derive mathematical equations (models) of each power system element
- Determine the coupling between each element
- Using known input, output and system parameter data, check that your model correctly simulates system behavior
- Use the model to predict system behavior with new input data scenarios

Neural Networks

Exercise: Pendulum Man

- How would you model the behavior of this system using
  - Dynamic system modeling
  - Neural network modeling

Summary

- Introduction to simulation
- Introduction to dynamic systems
- Introduction to neural networks
  - Compare and contrast dynamic systems and neural net modeling
- Matlab review