Modeling Dynamic Systems

An introduction to System Dynamics Modeling

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Environmental Evaluators Networking Conference

June 7 and 8, 2010

What's it all about?

- Methodology for studying and managing complex feedback systems
  - Management
  - Public Policy
  - Environment
  - Energy
  - Industry
- The recognition of and use of feedback loops differentiates System Dynamics from other systems approaches

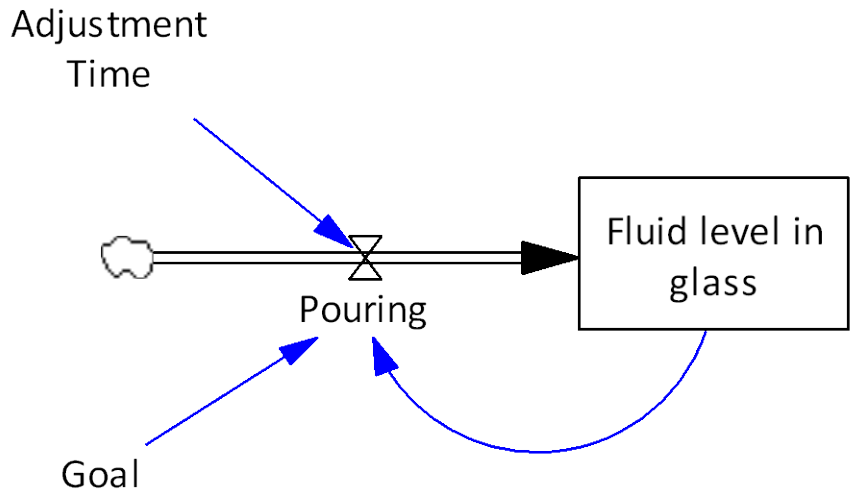
The methodology is used to…

- Develop a *dynamic hypothesis* about the cause of a problem
- Build a computer simulation model of the system at the root of the problem
- Devise and test alternative policies that alleviate the problem

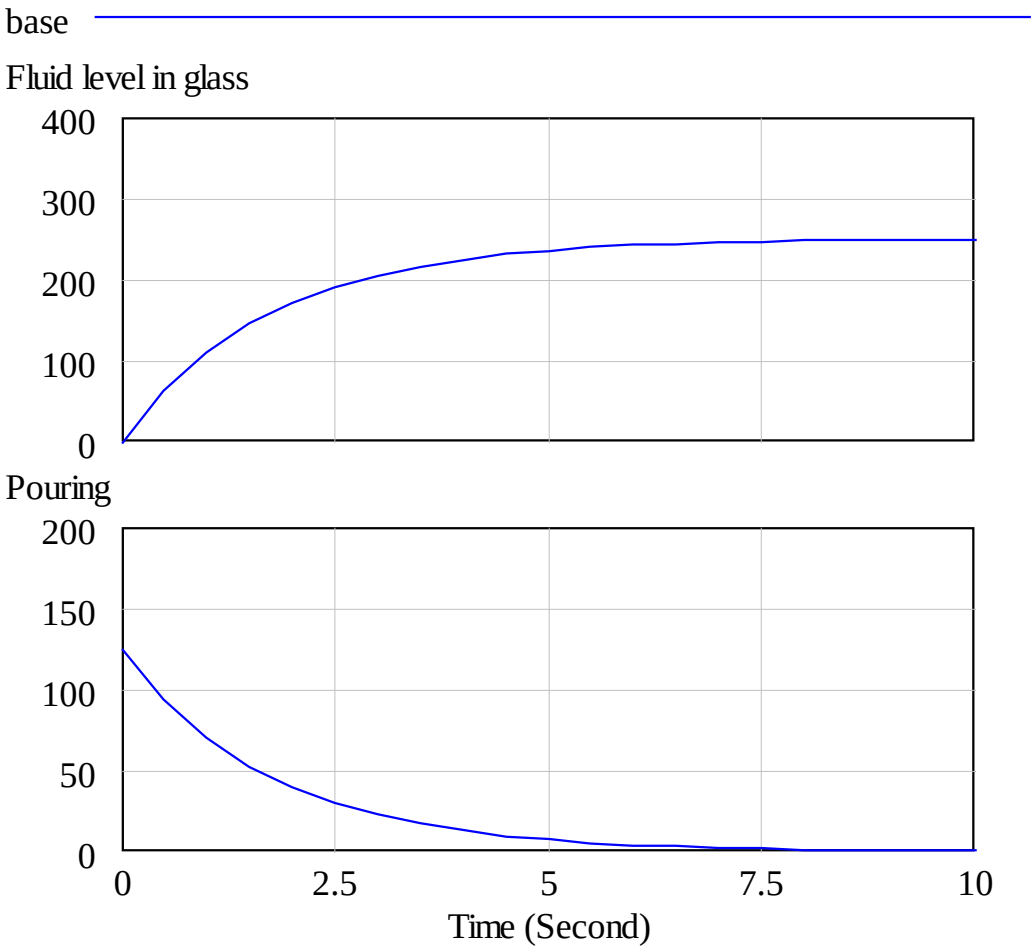
Computer Simulations that will…

- Illustrate causal feedback loops
- Explore non-linear relationships
- Be calibrated to existing data so that the model data is consistent with observed system behavior
- Help decision makers rely less on mental models

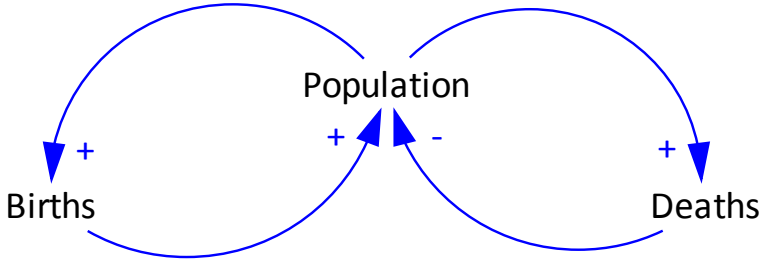
An example with which we are all familiar…



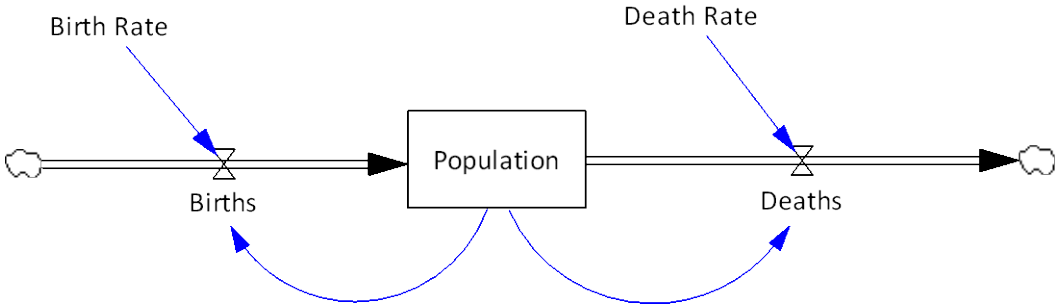
The data produced by the system



A Feedback Loop…



Depicted as a stock and 2 flows



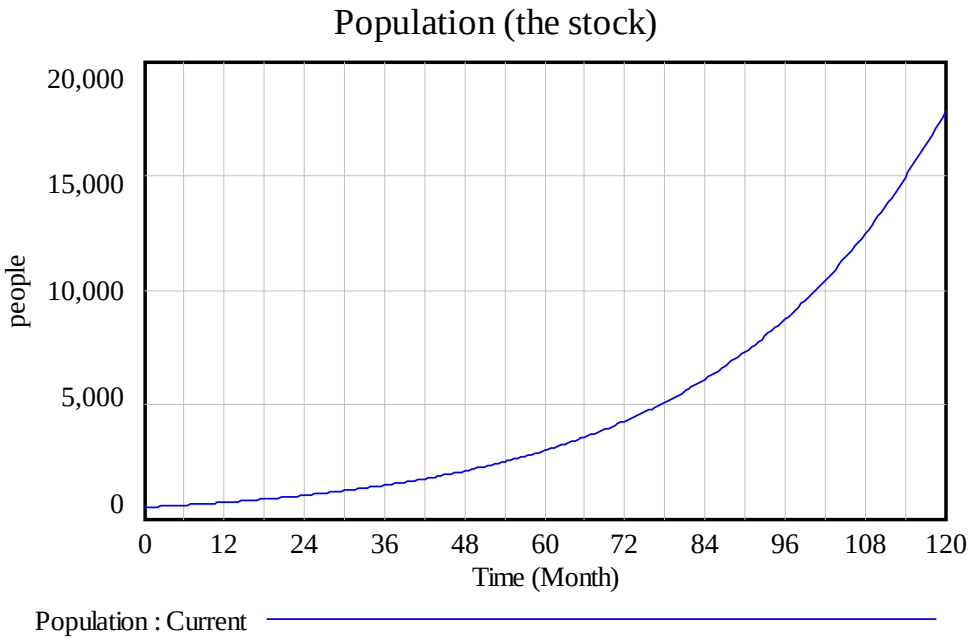
Stocks = accumulations over time

$$\text{Stock}(t) = \int[\text{Inflows} - \text{Outflows}] + \text{Stock}(t_0)$$

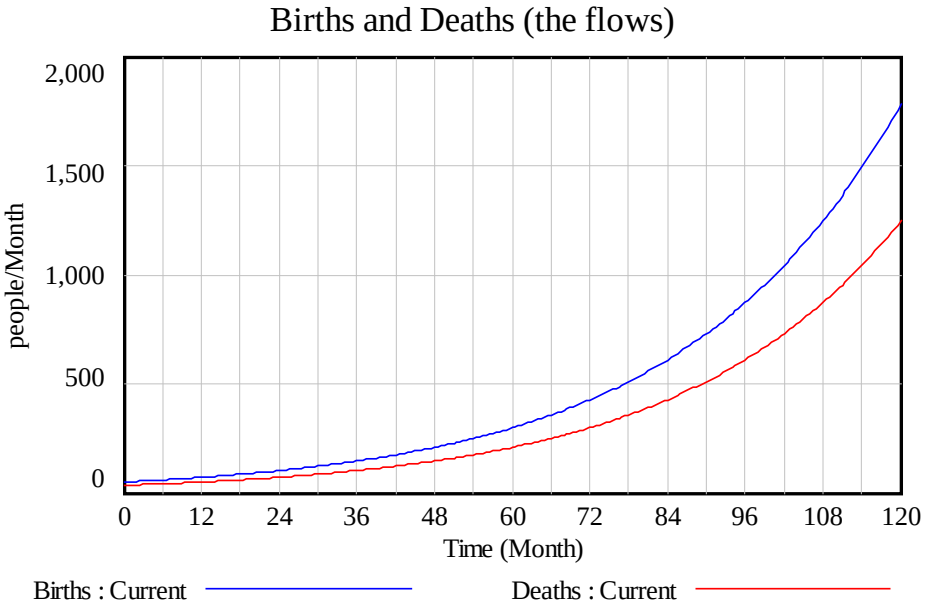
Flows = Changes in accumulations over time

So, the net change in a stock is just the derivative:

$$\partial(\text{Stock}) / \partial t = \text{Inflow}(t) - \text{Outflow}(t)$$

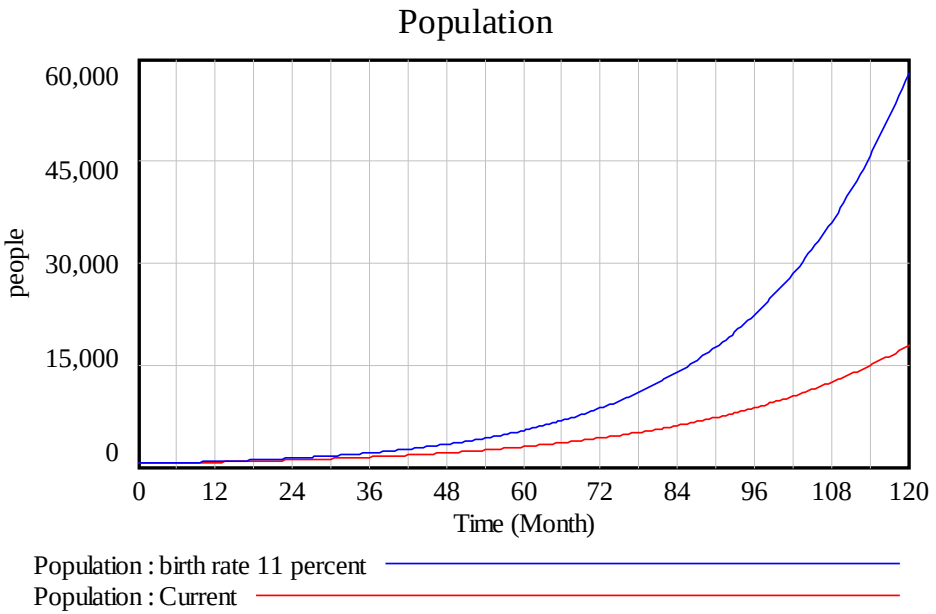


If the net inflow to a stock is greater than the net outflow, growth occurs. If the converse is true, decay occurs.

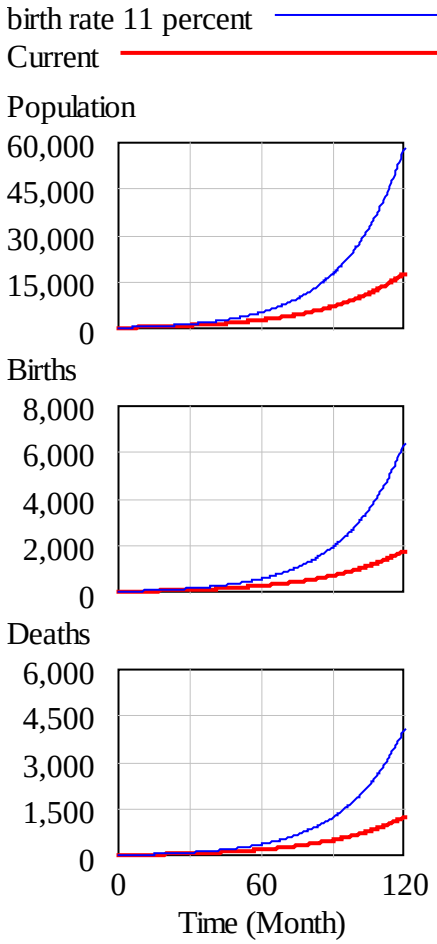


Using these basic tools, we can…

- Better understand how variables may interact over time, especially where nonlinear relationships come into play
- Better understand complex behavior of systems over time
  - Feedback Loops
  - Delays
- Discuss, develop, and simulate solutions to complex problems in a manner that is cost and time efficient



Data from the models can help us to understand the behavior of key variables over time relative to some ideal behavior (reference).



Easily compare data between variables within the same simulation run

or

Easily compare data between two separate simulation runs

World 2

- Constructed by Jay Forrester, MIT
- Central Question:
  - How may the expanding global population and material economy interact with and adapt to the earth's limited carrying capacity over the coming decades?

(World2 is a System Dynamics model that was explored during the session. Contact me if you would like to obtain it.)

What SD models *cannot* do…

- Predict the future (sorry!)
  - A common misconception
- Produce accurate predictions of discrete data points

Resources

- On the web:
  - www.vensim.com
    - You can download a free version of vensim for personal use
  - www.ventanasystems.com
  - www.systemdynamics.org
  - www.ventanasystems.com
  - www.iseesystems.com

References

- Forrester, J. (1959). *Urban Dynamics.*
- Meadows, D., Randers, J., & Meadows, D. (2004). *Limits to Growth.*
- Sterman, J. (2000). *Business Dynamics.*

Contact

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