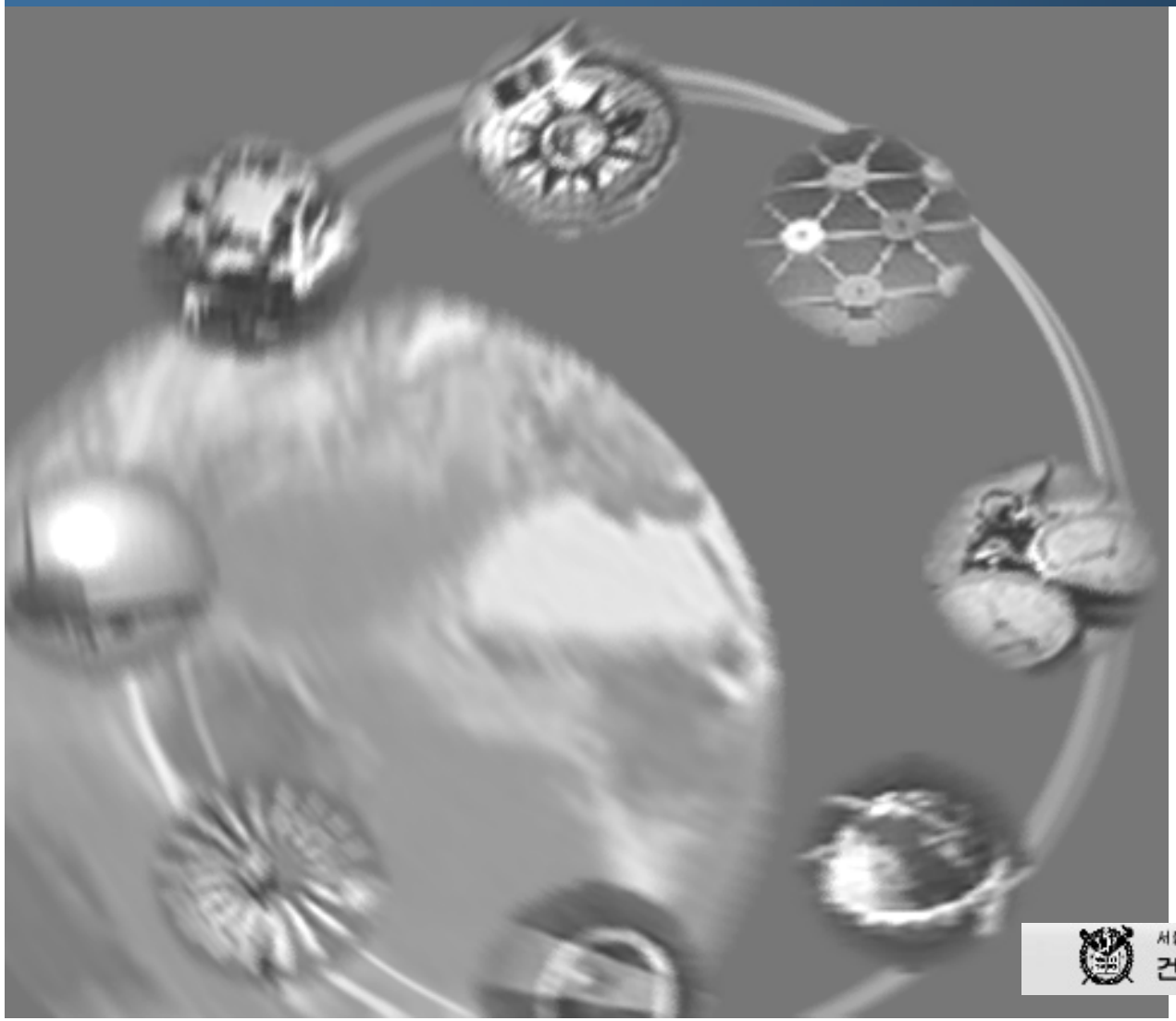
Closing the loop

Dynamics of Simple Structures

401.661 Advanced Construction Technology

Nov. 14th, 2006



Moonseo Park

Assistant Professor, PhD

39동 433
Phone 880-5848, Fax 871-5518
E-mail: mspark@snu.ac.kr

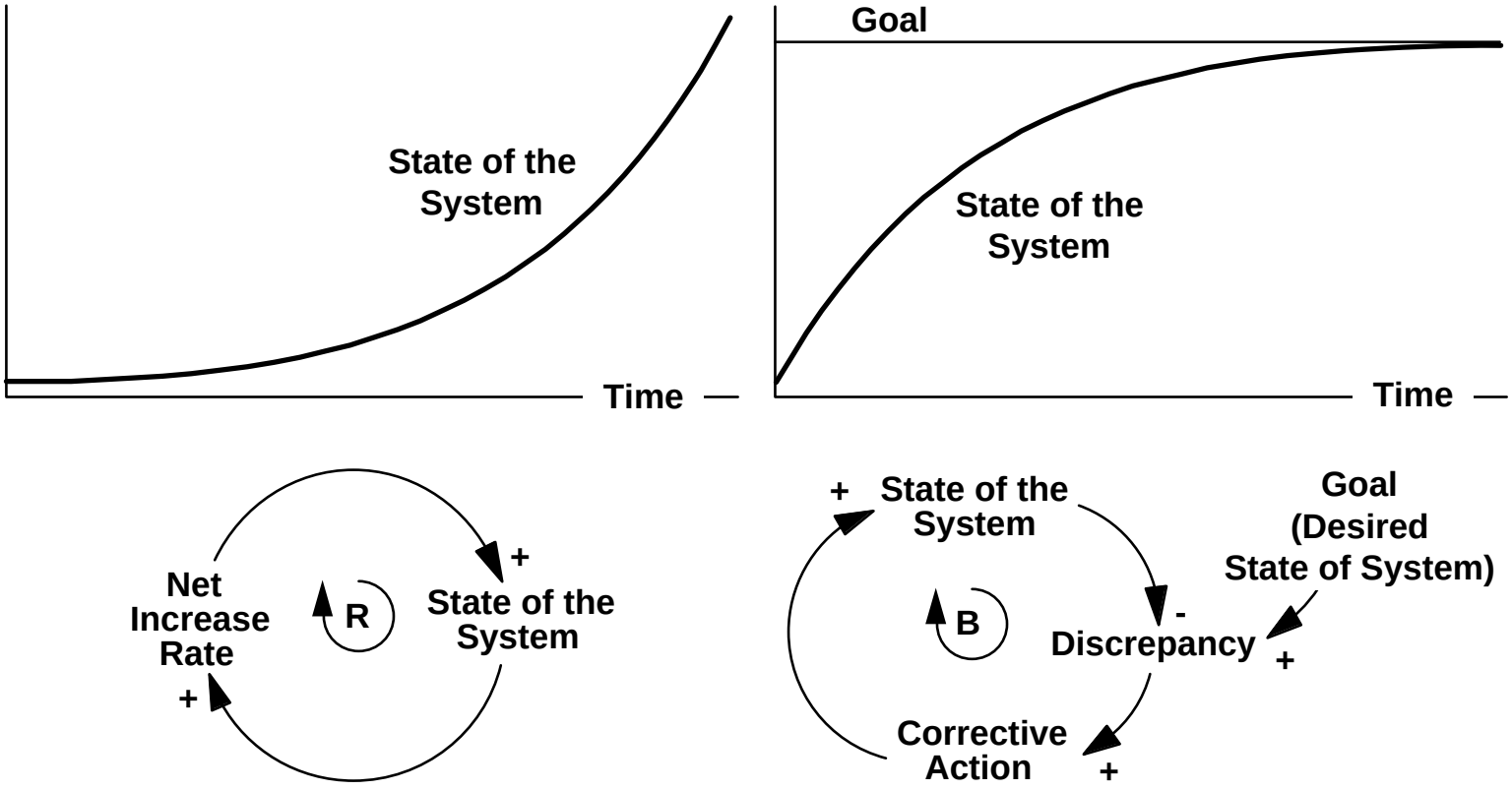
Department of Architecture
College of Engineering
Seoul National University

서울대학교 건설기술연구실

과학기술부 국가지정연구실 National Research Lab.

Fundamental Modes

- Positive feedback causes exponential growth, while negative feedback causes goal-seeking behavior.



First-Order Systems

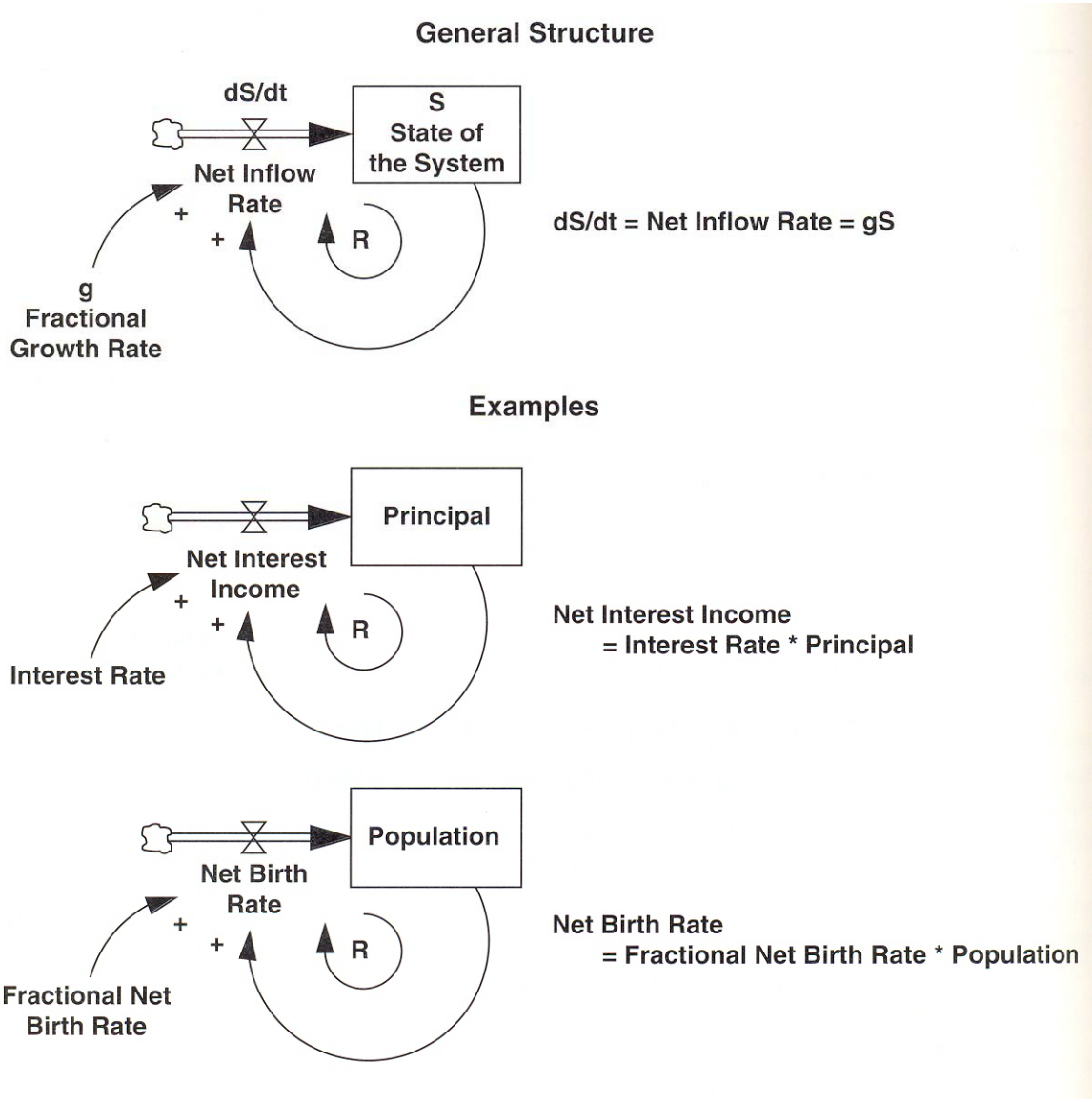
- A first-order system contains only one stock.

- Linear systems are systems, in which the rate equations are linear combinations of the state variables.

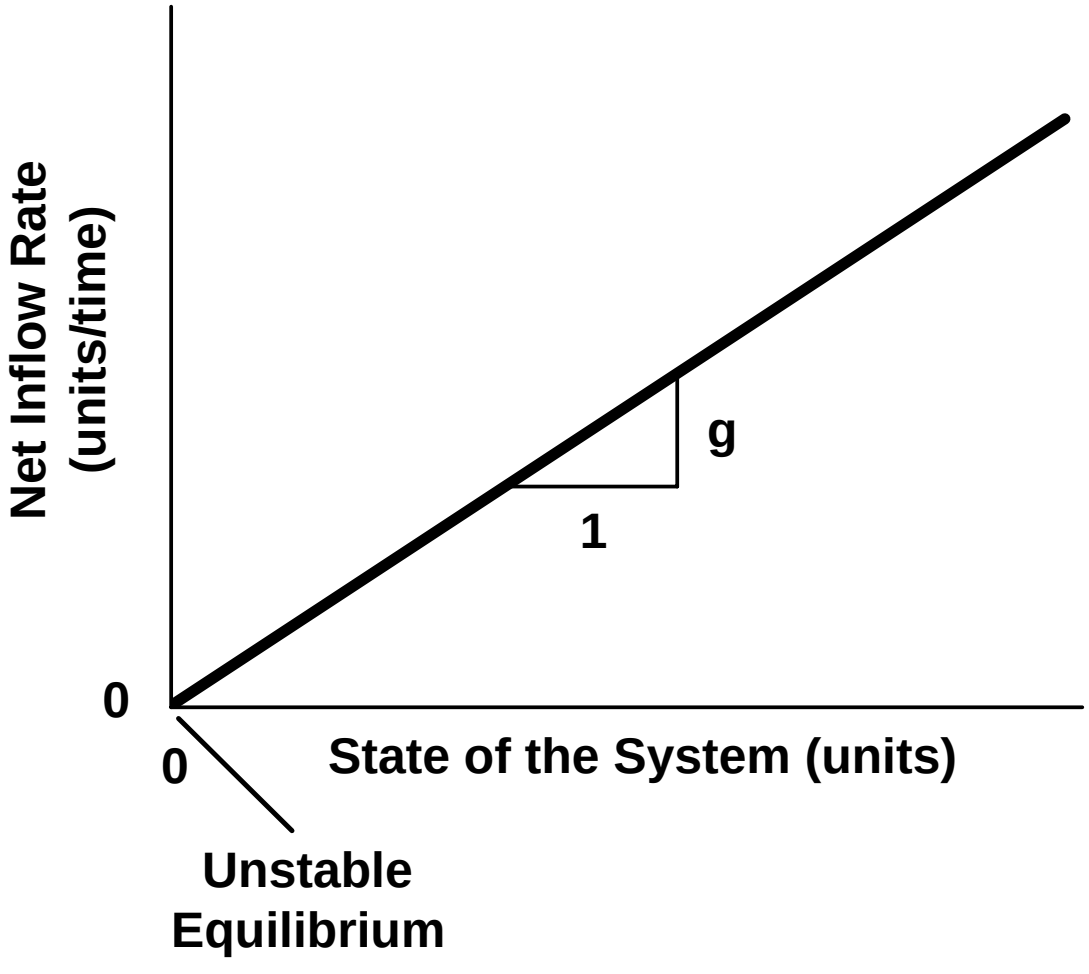
$$dS/dt = \text{Net Inflow} = a_1S_1 + a_2S_2 \ldots + a_nS_n + b_1U_1 + b_2U_2 \ldots + b_mU_m$$

Where the coefficients a_i, b_j are constants and any exogenous variable are denoted U_j.

First-Order Positive Feedback Loop



dS/dt = Net Inflow Rate = gS



Phase plot for the first-order, linear positive feedback system

Power of Positive Feedback

- Paper Folding
- The Rule of 70

Positive feedback leads to exponential growth, when the fractional net increase rate is constant.

$2S(0) = s(0)\exp(gt_d)$

$t_d = \ln(2)/g$, where $\ln(2) = 0.6931\ldots$

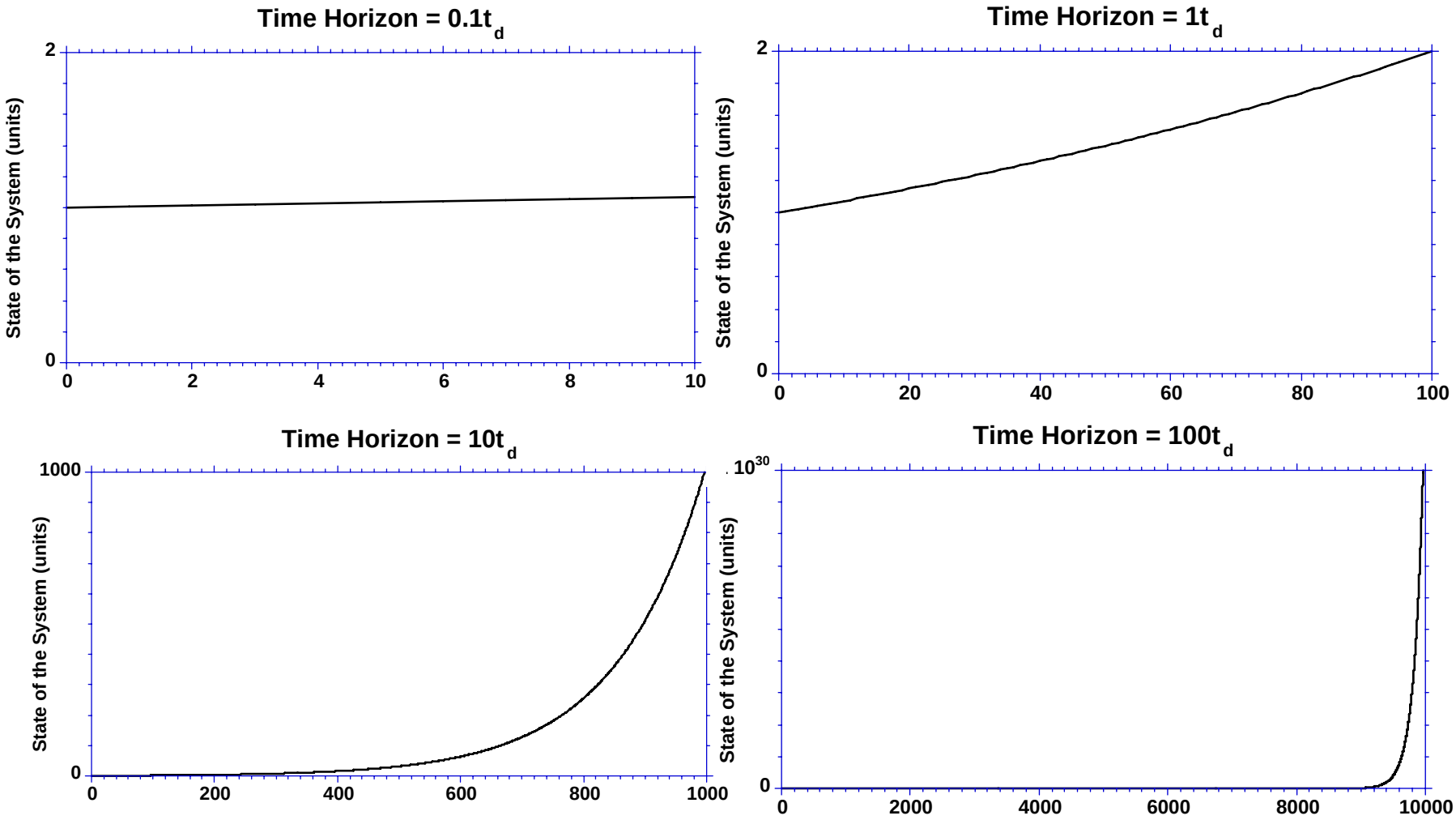
$t_d = 70/(100g)$

E.g., an investment earning 7%/year doubles in 10 yrs

Misperception of Exponential Growth

- We tend to assume a quantity increases by the same *absolute* amount per time period, while exponential growth *doubles* the quantity in a fixed period of time.

- The counterintuitive characters of exponential growth can be seen by examining it over different time horizons.



Exponential growth over different time horizons

The state of the system is given by the same growth rate of 0.7%/time period in all cases (doubling time = 100 time periods).

- No real quantity can grow forever (positive feedback processes approach their limits rapidly and often unexpectedly).

An old French riddle

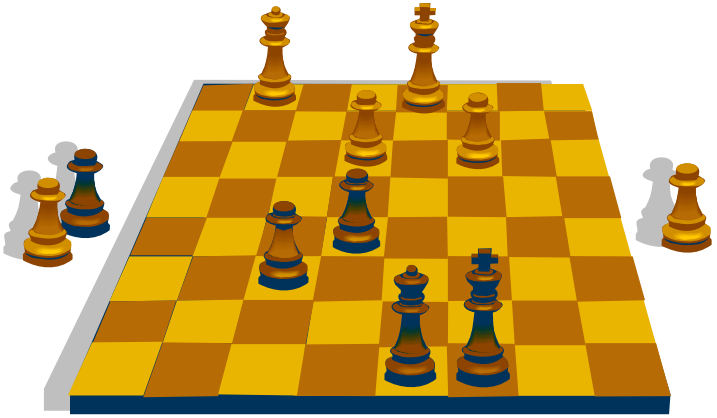
- A water lily doubles in size each day.
- It would completely cover the pond in 30 days.
- On what day will it cover half the pond so you have to cut it back?

- As limits are approached, nonlinearities always weaken the positive loops and strengthen the negative feedbacks.

<u>An old Persian legend</u>

- A courtier presented a chessboard to his king.
- Requesting the king give him in return a grain of rice for the square of the board, 2 grains for the 2nd square…
- Is it feasible?

* The total quantity of rice on all 64 squares would cover all of Iran to a depth of more than 5 feet.



Overconfidence

- Overconfidence: the confidence bounds people provide around their estimate of an unknown quantity are too narrow.
- More information, more confident, while accuracy did not improve.
- Thousands of repetitions provide feedbacks enabling to learn from experience (weather forecast, gambling) but there is little chance to learn from experience in most social/business situations.

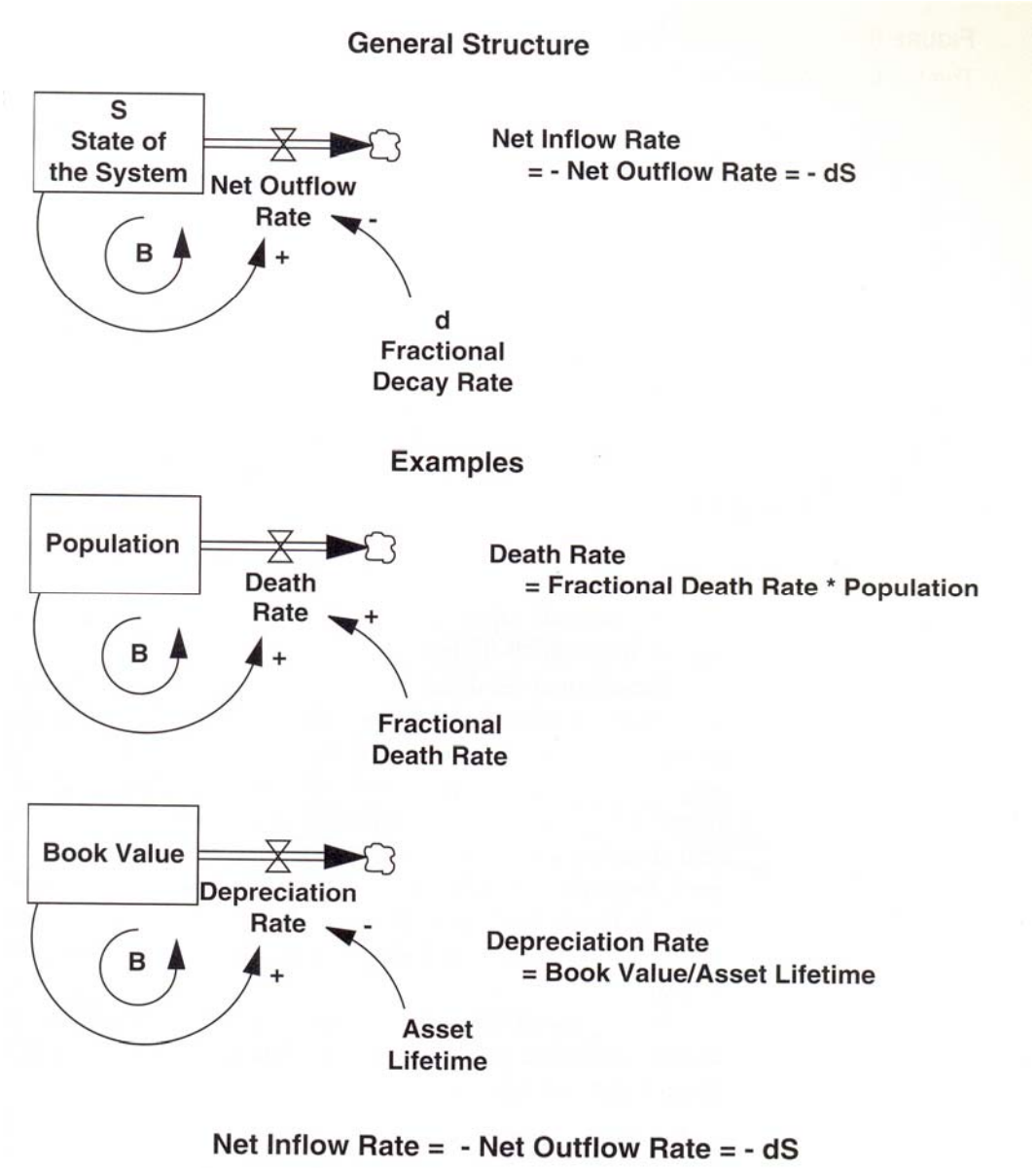
  Examples:
  - The Challenger explosion estimated 1 in 100,000.
  - Underestimating the likelihood of declining share price during 1920s and 1980s-90s

Overcoming Overconfidence

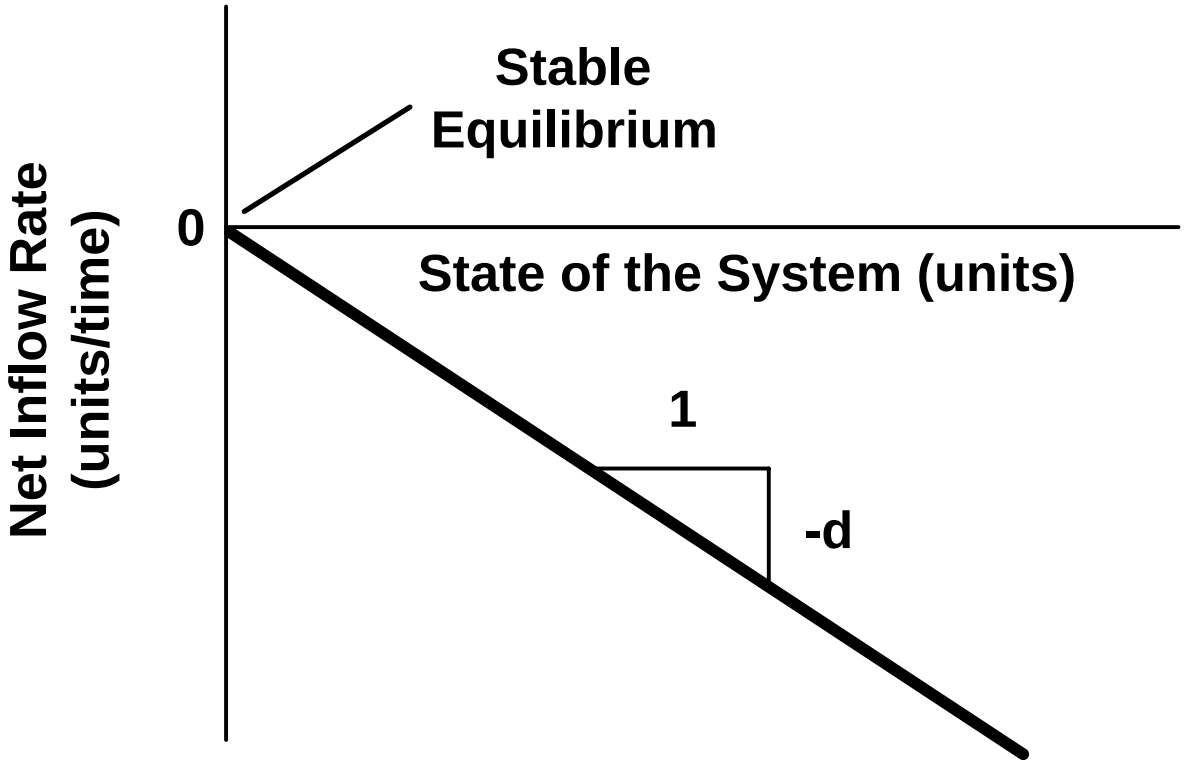
- List all the reasons your opinion could be wrong.
- Solicit the opinions of a diverse group especially those with opposite views.
- Suspect statements that something is absolutely certain, inevitable or a one in million chance.
- **When formal models are available, conduct extensive sensitivity tests.**

Negative feedback and Exponential Decay

- First-order negative feedback systems generate goal-seeking behavior. When the system is linear, the behavior is pure exponential decay.



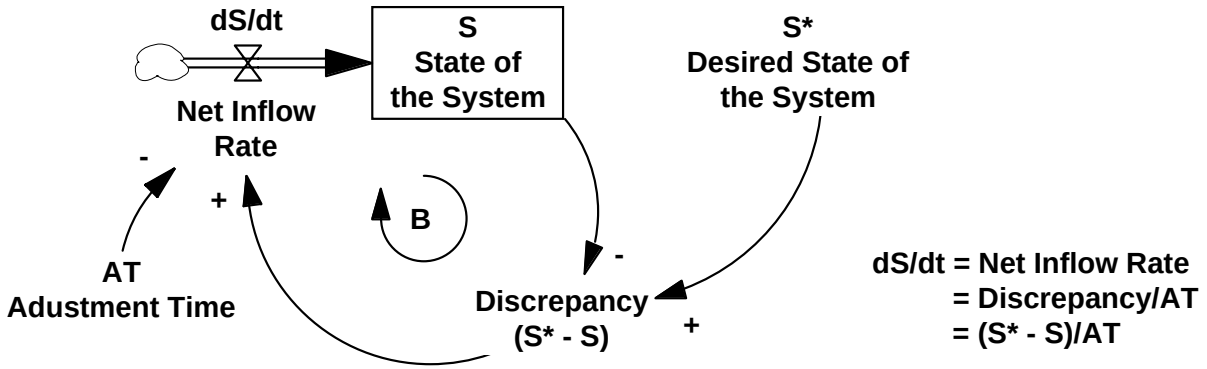
Net Inflow Rate = - Net Outflow Rate = - dS



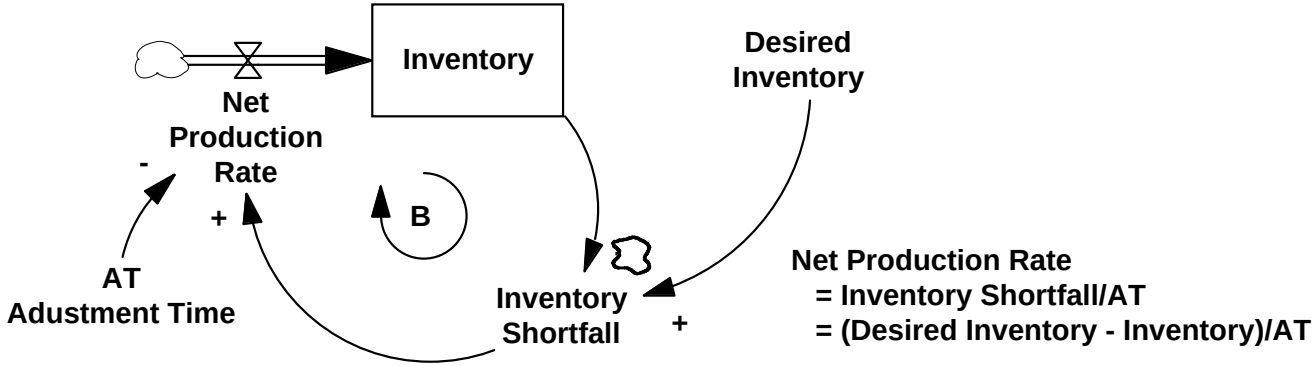
Phase plot for exponential decay via linear negative feedback

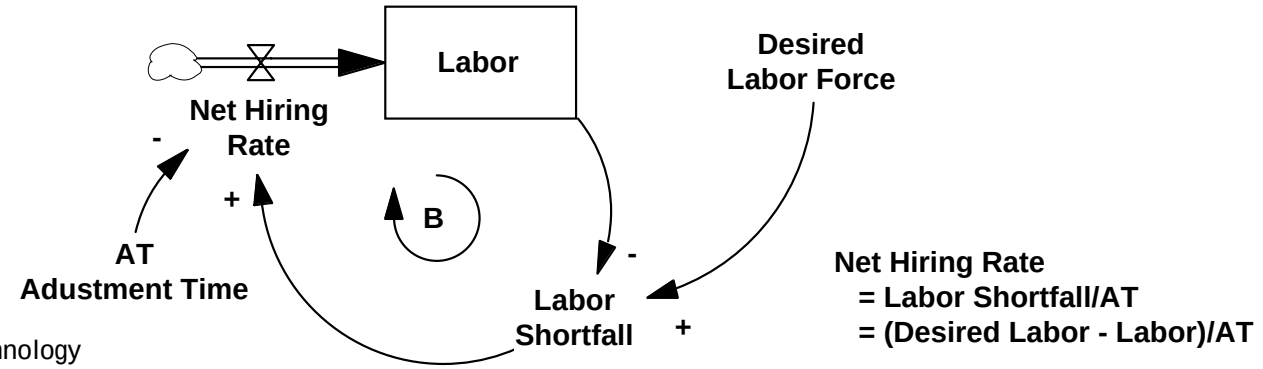
First-order linear negative feedback system with explicit goals

General Structure



Examples





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