

# Forrester System Dynamics

- based on observation + physical insight
- semi-physical, semi-inductive *methodology*

## Methodology

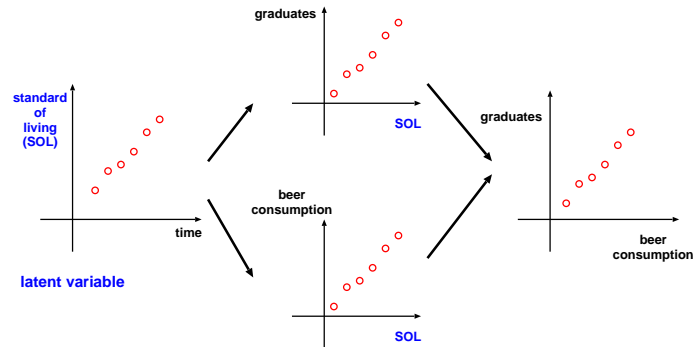
1. levels/stocks and rates/flows

$$\frac{dP}{dt} = BR - DR$$

Level	Inflow	Outflow
population	birth rate	death rate
inventory	shipments	sales
money	income	expenses

2. laundry list: levels, rates, and influences  
birth rate → birth → population
3. Influence Diagram (+ and -)
4. Structure Diagram

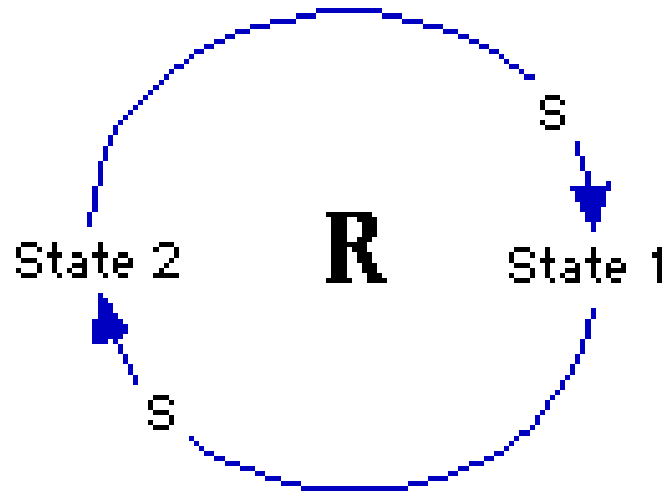
# Causal Relationships



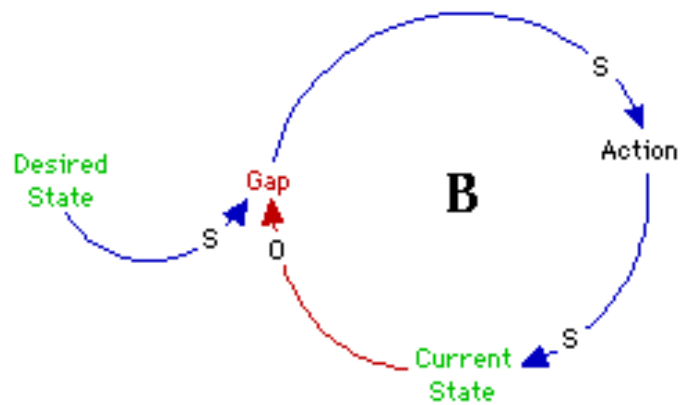
# Archetypes

- Bellinger <http://www.outsights.com/systems/>
- structure diagrams
- Common combinations of reinforcing and balancing structures

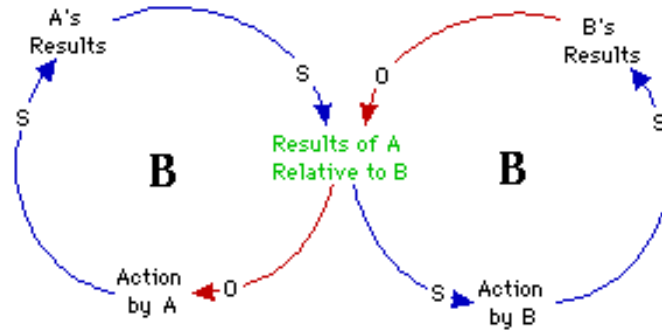
## Archetypes: Reinforcing Loop



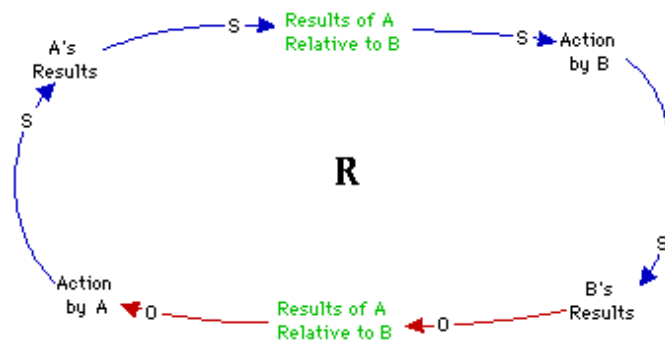
## Archetypes: Balancing Loop



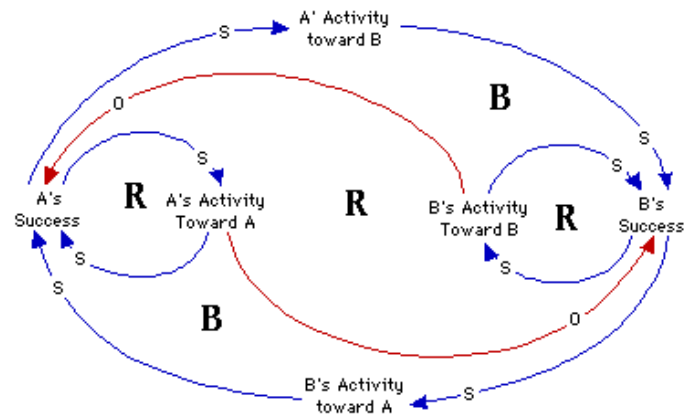
# Archetypes: Escalation



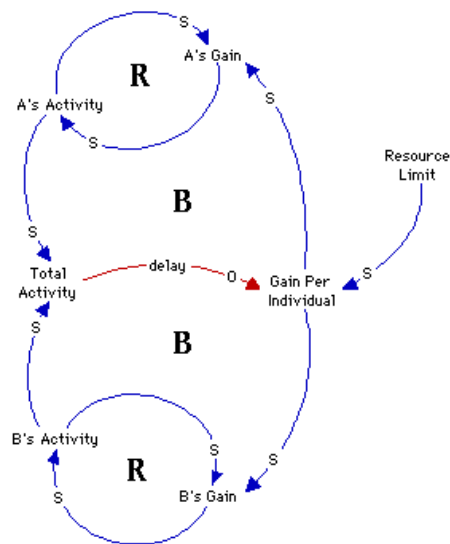
# Archetypes: Escalation Unrolled



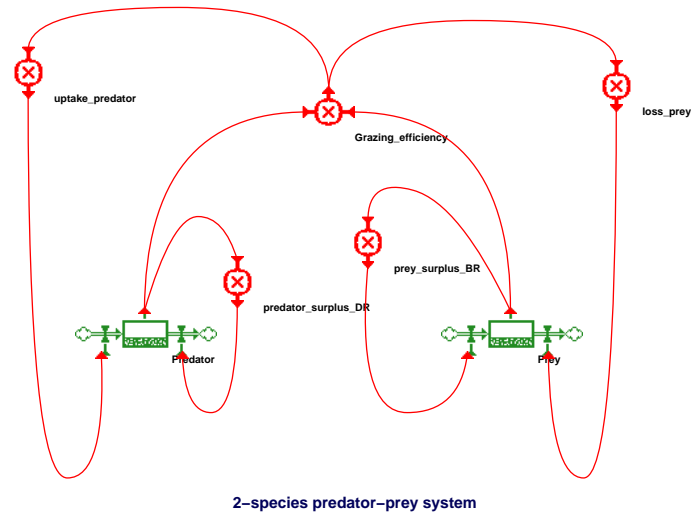
## Archetypes: Accidental Adversaries



## Archetypes: Tragedy of the Commons



# Forrester System Dynamics



## Inductive Modelling: structure

$BR = f(\text{POP}, \text{POL}, \text{MSL}, \dots)$

$BR = \text{BRN.f1}(\text{POP}, \text{POL}, \text{MSL}, \dots)$

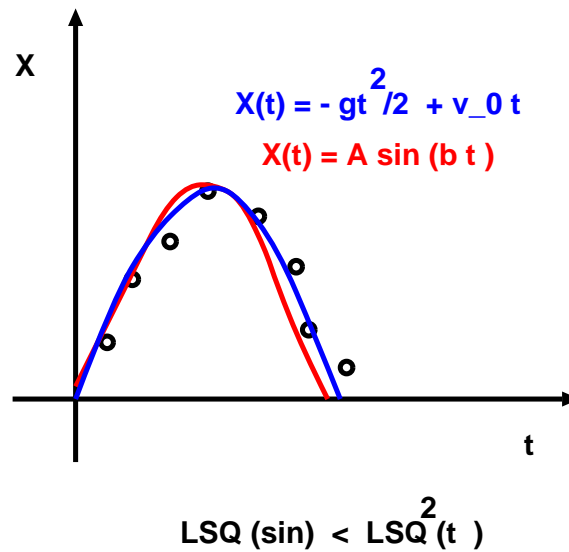
$BR = \text{BRN.POP.f2}(\text{POL}, \text{MSL}, \dots)$

$BR = \text{BRN.POP.f3}(\text{POL}).\text{f4}(\text{MSL}). \dots$

$\text{f3}(\text{POL}) = \text{"inversely proportional"}$

$\text{f4}(\text{MSL}) = \text{"proportional"}$

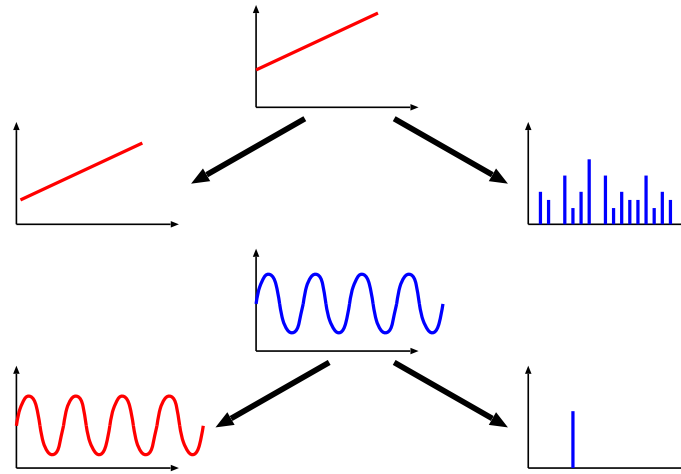
## Structure Characterisation: LSQ fit



## Feature Extraction

1. Measurement data *and* model candidates
2. Structure selection and validation
3. Parameter estimation
4. Model use

## Feature Rationale



Minimum Sensitivity to Noise  
Maximum Discriminating Power

## Throwing Stones

### Candidate Models

1.  $x = -\frac{1}{2}gt^2 + v_0t$
2.  $x = A\sin(bt)$



## Feature 1 (quadratic model)

$$g_i = \frac{2x_i}{t_i^2} - \frac{2\dot{x}_i}{t_i}, i = A, B$$

$$F1 = g_A/g_B$$

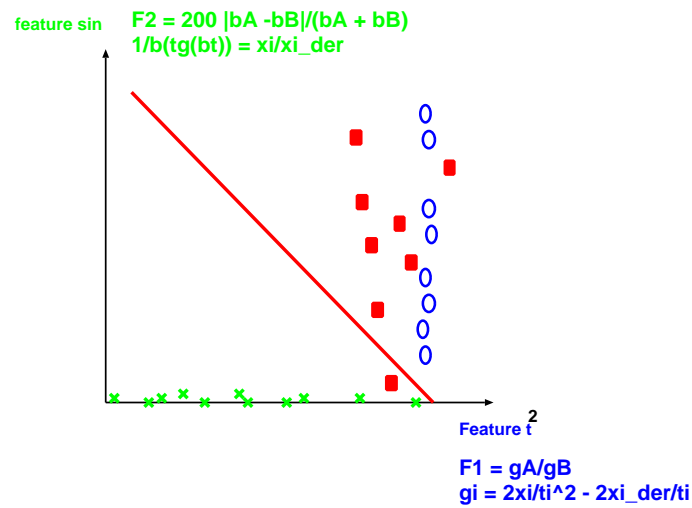
## Feature 2 (sin model)

$$\frac{1}{b}tg(bt) = \frac{x_i}{\dot{x}_i}$$

solve numerically for  $b$

$$F2 = 200 \frac{|b_A - b_B|}{b_A + b_B}$$

# Feature Space Classification



# Pandemomium Model

