GENERAL SYSTEM THEORY

Tiago Garcia de Senna Carneiro
Head of TerraLAB – INPE/UFOP laboratory for Earth Systems Modeling and Simulation

Theory plays an important role in all the arts and arts sciences by:

- Providing for the unification and classification of available knowledge
- Suggesting the design of experimental studies that will broaden our present scope of knowledge.

General Systems Theory (GST) Historical Background

- GST was originally enunciated by Ludwig Von Bertalanffy.
  - The Charles Morris Philosophy Seminar at the University of Chicago 1937.
  - An outgrowth of his work in biology
  - He first developed his thoughts on the European continent in the 1920's

General Systems Theory (GST) Historical Background (Cont.)

– After the war a change in the intellectual climate had taken place.

– The change made the atmosphere appropriate for further presentation of this new theory called General Systems.

– Other scientists had followed similar lines of thought and to Bertalanffy's satisfaction GST was not a personal idiosyncrasy but corresponded to a trend in modern thought.

Major Proponents

- Parallel developments went on in Anglo-Saxon countries (Whitehead, Woodger, Coghill and others, old English/Germanic peoples).

- In psychological Gestalt Theory (W. Kohler)

- A similar development in psychiatry represented by Goldstein and it continued through Cannon's work in physiology.

- Similar developments went on in communication, engineering, computers, servo-mechanisms,Cybernetics

Major Proponents (Cont)

– Similar trends were active in many fields of the behavioral sciences

– Heavy impetus on GST came from Bertalanffy in 1950 with his classic article in the British Journal for the Philosophy of Science, entitled “An Outline of General Systems Theory”

Major **Proponents** (Cont.)

- A host of others in the 1950's that introduced GST in their disciplines represented a diverse mixture of academic training:
  - Parsons, a sociologist (1951)
  - J.G Miller a Psychiatrist & Psychologist (1955)
  - Boulding, an economist (1956)
  - Rapoport. A mathematician (1956)
  - Ashby, a bacteriologist (1958)

Major Proponents (Cont.)

- Berrien, in his book General and Social Systems (1968) expressed the idea that systems theory was seen by many as having the potential for spanning the natural and social sciences by offering a common framework for the various disciplines

Major Proponents (Cont.)

- In 1954 the society for general systems research was established by Bertalanffy, Boulding, A. Rapoport, and Gerard:
  - “ to further the development of theoretical systems which are applicable to more than one of the traditional departments of knowledge”

General Systems Theory: The Basic Construct

- System definition:
  – Systems are bounded regions in time and space involving energy interchange among their parts, which are associated in functional relationships, with their environment.

General Systems Theory: The Basic Construct (Cont.)

- System definition <u>stated more simply</u>:
  - "A set of objects together with relationships between the objects and between their attributes."

General Systems Theory: The Basic Construct (Cont.)

- System definition stated most simply:
  - "Sets of elements standing in interaction."

Structural Components of General Systems (GST)

- Subsystems:
  - Every system, with the exception of the smallest, has subsystems which are smaller entities within that system which have all the characteristics necessary to be a system

GST Components (Cont.)

- Suprasystems:
  - All but the largest system are a part of a suprasystem, systems outside of and larger than one being considered.

GST Components (Cont.)

- Environment:
  - The environment of a system is everything external to its boundaries.
  - Higher orders of systems, consequently, are always part of the environment of lower orders.

GST Components (Cont.)

- Types of Environment:
  - Proximal Environment– That part of the environment of which the system is aware.
  - Distal environment– That part of the environment beyond the awareness of the system.

GST Components (Cont.)

- Variables & Parameters:
  - There are factors in both the system and the environment which effect their respective structure and function (heat, cold, light, etc.)
  - Variables: Those factors in a system or its subsystems are called variables.
  - Parameters: Those factors in the environment or suprasystem are called parameters.

GST Components (Cont.)

- Open & Closed Systems:
  - Closed Systems –
    - Those that do not exchange energy or information with their surroundings and therefore function totally within themselves.
  - Open Systems
    - Those that do exchange energy or information with their surroundings (environment).
      All living organisms are open systems
    - A Circle is typically used as a graphic representation of a system.

GST Components (Cont.)

- Entropy and Negative Entropy:
  - Newton ‘s Second Law of Thermodynamics
    - Holds that unattended systems proceed relentlessly toward disorder & disorganization or what is called Entropy.
    - Entropy is constant in the universe, it can not be destroyed. It ends when a steady state or equilibrium is reached .
    - Negative Entropy (negentropy) is the opposite of entropy and represents the necessity of any system to prevent disorganization.

GST Components (Cont.)

- Boundaries:
- That region separating one system from another.
- Without exception it is an arbitrary designation
  - Boundaries may not always be clear-cut, and may be determined in several ways.
  - Examples: (shore line, atmosphere and earth, ingredients in a compound, chemical in the air, gases, etc.)
- The function of a boundary is to filter or select what goes in (unput) and what comes out I (output).

GST Components (Cont.)

- Input - Throughput - Output
  - These concepts are true only of open systems
- Input: Those energies or information absorbed through the boundary into a system
  - Inputs are considered to have two types:
    - Maintenance Inputs - Those which energize the system and make it ready to function
      - (Gas/Car. Electricity/Radio, Water/Plant etc)
    - Signal Inputs:- Those which supply the system information to be processed.
      - (Data/Computer, facts/decision making)

GST Components (Cont.)

- Feedback
- The process by which the system regulates its responses to outside stimulations.
- Feedback is the control of inputs as a function of outputs.
- It is the process of measurement of inputs and outputs then maintaining a balance or steady state.

GST Components (Cont.)

- Feedback (Cont.)

- Through the process of feedback systems are able to adjust future conduct by past experience.
  - A certain portion of the systems output or behavior is fed back in the form of input to affect succeeding outputs.

GST Components (Cont.)

- Feedback (Cont.)

- Feedback can be classified as negative or positive.
- Negative Feedback:
  - Maintenance input which enables the system to correct deviations and support the steady state.
    - Example, the feedback says make changes or your not in balance (negative message to the system.
    - If negative feedback is ignored the the boundaries of the system disappears and the system ends .
      - (i.e. A car engine is destroyed if the thermostat is broken or ignored)

GST Components (Cont.)

- **Feedback** (Cont.)

- Positive Feedback:
  - Signal input which changes the variables of the system and changes the steady state.

GST Components (Cont.)

- **Homeostasis**
  - The tendency of any systems to maintain themselves in a steady state.
  - This constant effort to maintain such a balance we call homeostasis, or steady state
  - If homeostasis is disrupted and the system can’t adjust through its feedback mechanisms that system ends (i.e body temp.)

GST Components (Cont.)

- **Homeostasis** (Cont.)
  - Dysfunction in a system is a consequence of a disturbance in the systems homeostasis, or the
  - This constant effort to maintain such a balance we call homeostasis, or steady state
  - If homeostasis is disrupted and the system can't adjust through its feedback mechanisms that system ends (i.e body temp.)

GST Components (Cont.)

- **Homeostasis (Cont.)**

  – Dysfunction in a system is therefore a consequence of a disturbance in the systems homeostasis or the ability to maintain a steady state.

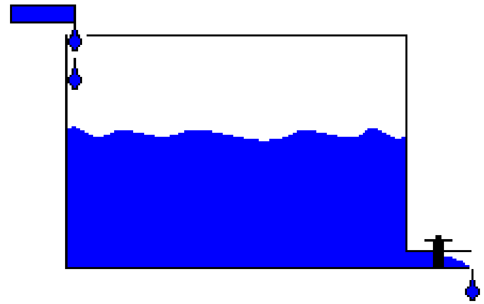
GST Components (Cont.)

- **Equifinality**
  - Simply means that in open systems achieving of identical results from different initial conditions may occur.

Pratice

- Drenage Modeling -

Realidade

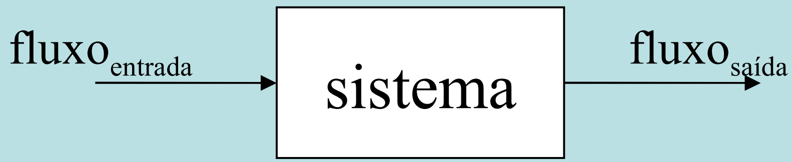


caixa d’agua com torneira semi-aberta

Questão: quanta água há na caixa d’agua?

Modelo Conceitual

Teoria de Sistemas



fluxo pode ser de matéria, energia ou informação

Questão: quanta matéria há no sistema?

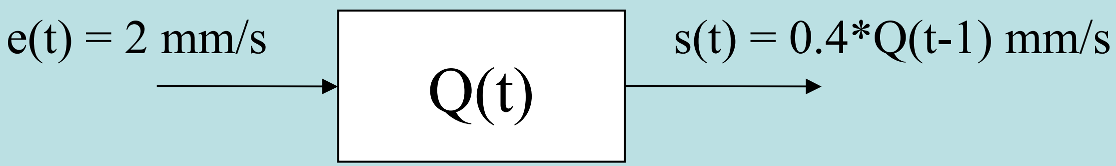
Hipótese: a quantidade de matéria na saída é proporcional à quantidade retida no sistema

Modelo Conceitual

fluxo pode ser de matéria, energia ou informação

Questão: quanta matéria há no sistema em um dado momento?
Hipótese: a quantidade de matéria na saída é proporcional à quantidade retida no sistema

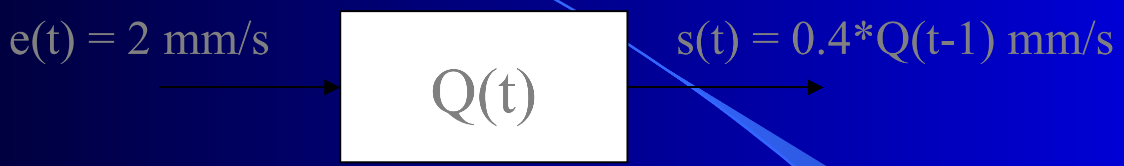
Modelo Matemático



$$\mathbf{Q(t) = Q(t-1) + e(t) - s(t)}$$

Questão: Q(t)?
Hipótese: s(t) = constante * Q(t-1)

Modelo Matemático



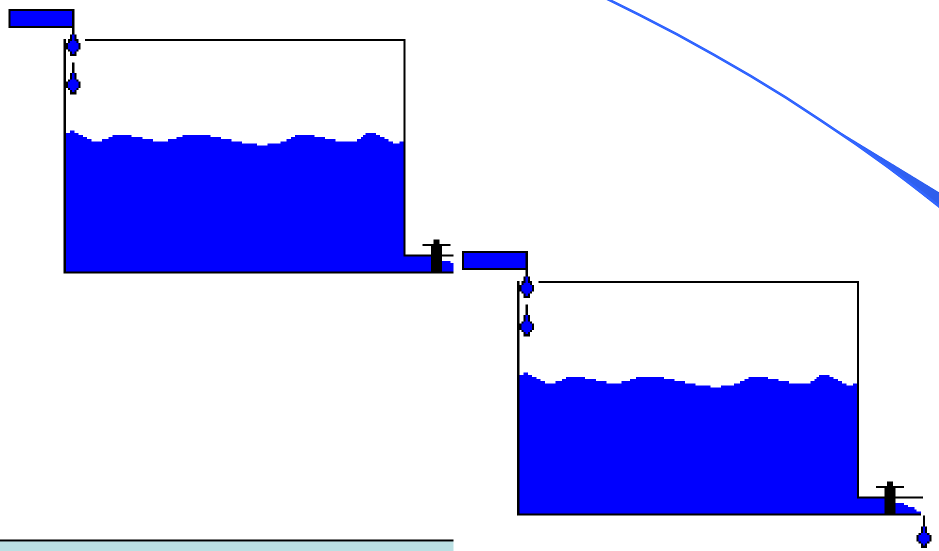
Q(t) = Q(t-1) + e(t) – s(t)

Questão: Q(t)?
Hipótese: s(t) = constante * Q(t-1)

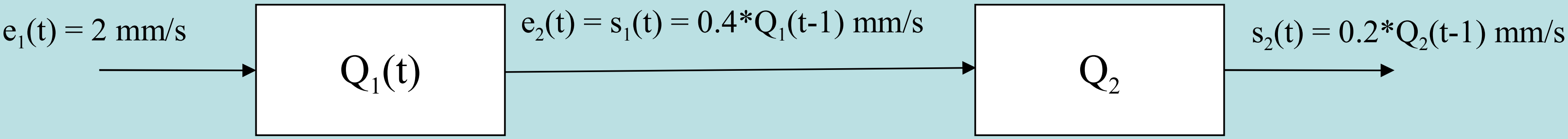
Modelo Computacional

```
-- Parametro
Q = 0;
for    t = t_inicial, t_final, 1    do
            -- Entrada
            E = 2;
            -- Saida
            S = 0.4 * Q;
            -- Simulacao
            Q = Q + (E - S);
end
-- Relatorio
print( Q );
```

Realidade



Modelo Matemático



Modelo Computacional

```
-- Parametro
Q1 = 0;
Q2 = 0;
for    t = t_inicial, t_final, 1    do
        -- Entrada
        E1 = 2;
        -- Saida
        S1 = 0.4 * Q1;
        -- Simulacao
        Q1 = Q1 + (E1 – S1);
        ---------------------
        -- Entrada
        E2 = S1;
        -- Saida
        S2 = 0.2 * Q2;
        -- Simulacao
        Q2 = Q2 + (E2 - S2);
end
-- Relatorio
print( Q1 + Q2 );
```