




# DEVS Training Course


## Class 02 - DEVS Programming - Part 2 - Theory and Hierarchy

Prof. Dr. Valdemar Vicente Graciano Neto

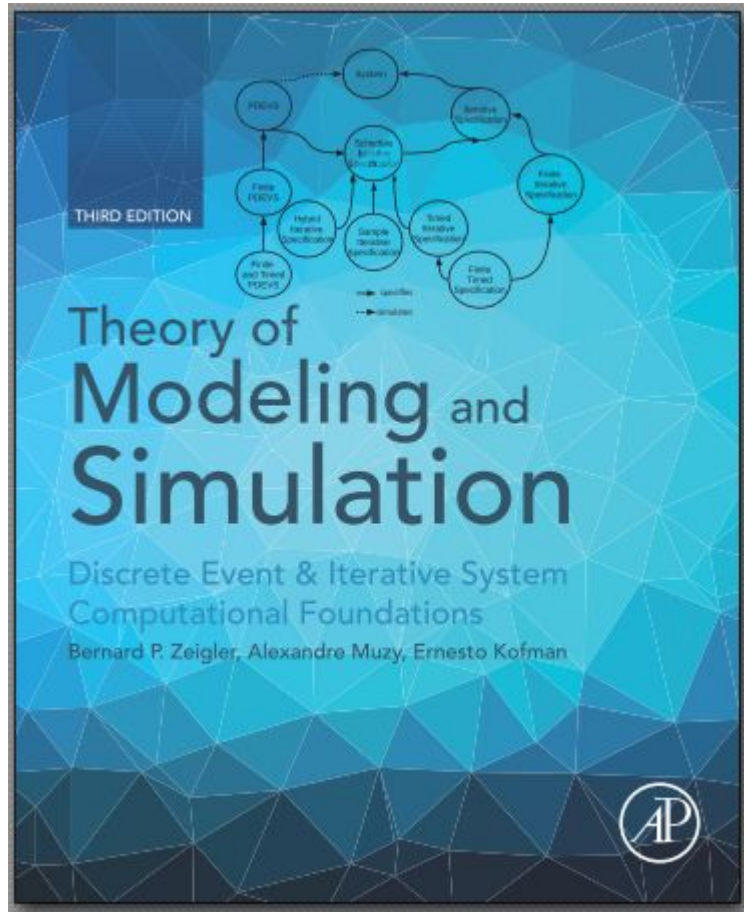
# In the previous class...

- 
- Data Types
  - Specifying ports
  - Changing the content of messages
  - Accessing message content
  - Events
  - Performing Processing on Atomic Models

# In this class...

- 
- Fundamentals of DEVS Theory
    - DEVS and DEVSNL
  - Some good programming practices to mention
  - Changing perspectives and composing models.

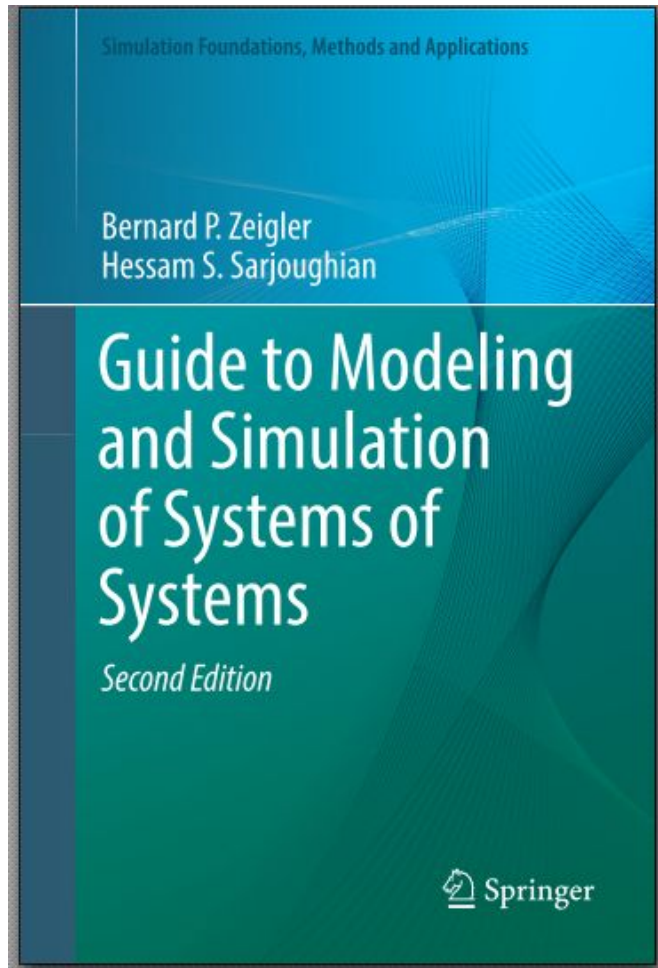
# Foundations for this class



Bernard Zeigler; Alexandre Muzy;  
Ernesto Kofman. Theory of Modeling and  
Simulation - Discrete Event & Iterative  
System Computational Foundations. 3rd  
Edition

Academic Press. 2018. 692 p.

# Foundations for this class



Bernard Zeigler; Hessam Sarjoughian.  
Guide to Modeling and Simulation of  
Systems of Systems. Springer.  
2013/2017. 400 p.



# Fundamentals and Theory in DEVS

# DEVS Fundamentals

## □ Classic DEVS - A Formal Definition for an Atomic Model

A Discrete Event System Specification (DEVS) is a structure

$$M = \langle X, S, Y, \delta_{\text{int}}, \delta_{\text{ext}}, \lambda, \text{ta} \rangle$$

where

$X$  is the set of input values

$S$  is a set of states,

$Y$  is the set of output values

$\delta_{\text{int}} : S \rightarrow S$  is the internal transition function

$\delta_{\text{ext}} : Q \times X \rightarrow S$  is the external transition function, where

$Q = \{(s, e) | s \in S, 0 \leq e \leq \text{ta}(s)\}$  is the total state set

$e$  is the time elapsed since last transition

$\lambda : S \rightarrow Y$  is the output function

$\text{ta} : S \rightarrow \mathbb{R}_{0,\infty}^+$  is the time advance function

# What can we do with DEVS/MS4ME?




- Change Perspectives (Not only top) and compose models
- Reuse simulation assets using Aspects
- Include libraries
- Receiving data in parallel (P-DEVS)
- Inheritance
- Assign probabilities to state transition
- Open files, streams and connection (Socket)
- Query the simulator object reflexively and modify it at runtime






# DEVS Practice


# DEVS Practice

- 
- Idea to be modeled
    - The Human Body has several systems, including the digestive, nervous, and circulatory systems.
    - The nervous system commands the others.
    - The circulatory system informs the nervous system that there are few nutrients.
    - Nervous system causes hunger.
    - When the individual eats enough, the digestive system sends the message of satiety to the nervous system.
    - The digestive system delivers nutrients to the circulatory system.

# DEVS Practice

- 
- Idea to be modeled
    - The circulatory system has the heart and veins as its main components;
    - The main components of the digestive system are the mouth, stomach, and intestine, where nutrients are absorbed and delivered to the circulatory system;
    - The stomach sends the satiety message to the nervous system.

# DEVS Practice

- 
- ▣ Changing perspectives (Hierarchical Construction)
    - Perspectives:
      - Body
      - Systems

# DEVS Practice

- ▣ Changing perspectives (Hierarchical Construction)
  - 1<sup>a</sup> Perspective - Body

From the body perspective, HumanBody is made of NervousSystem, DigestiveSystem, and CirculatorySystem!


From the body perspective, HumanBody sends Food to DigestiveSystem!

From the body perspective, DigestiveSystem sends Satiation to NervousSystem!

From the body perspective, DigestiveSystem sends Nutrients to CirculatorySystem!

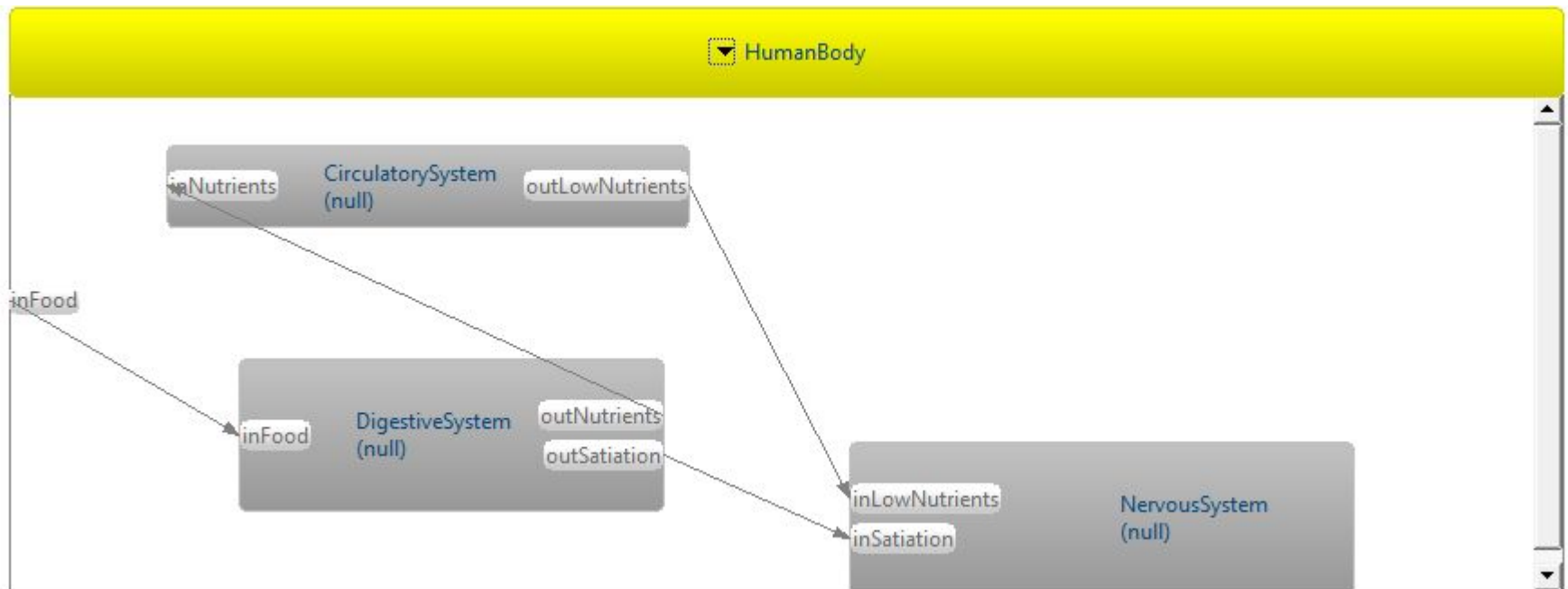
From the body perspective, CirculatorySystem sends LowNutrients to NervousSystem!

# Rules

- 
- **each element of a perspective only communicates with elements of the same perspective** (ex: c1 from top does not communicate directly with c1 of sos1, it needs to communicate with sos1 and sos1 passes to c1 of sos1).
  - **if a composite element receives something, some atomic model has to receive that something** (it can pass it to another composite element recursively, but in the end (in the sheet), an atomic model has to receive it) (eg for sos1 to send something to c1 from sos3 it sends to sos2, sos2 sends to sos3 and sos3 sends to c3).
  - **if an element from a perspective needs to send something to some element from a perspective above, it has to send it to the composite element** (its parent), and the element will send it to one of its perspective (this can happen recursively going up the tree) ( eg for c3 from sos1 send something to sos2, it sends it to sos1 (his father) and sos1 sends it to sos2).

# DEVS Practice

- Changing Perspective (Hierarchical Construction)
  - 1<sup>a</sup> Perspective - Body



# DEVS Practice

- 
- Changing Perspective (Hierarchical Construction)
    - A way to do it: using Aspects (HumanBody.ses)

From the top perspective, HumanBody is made of Systems!

**Systems can be NervousSystem, DigestiveSystem, or CirculatorySystem in nature!**

From the nervous perspective, NervousSystem is made of Brain!

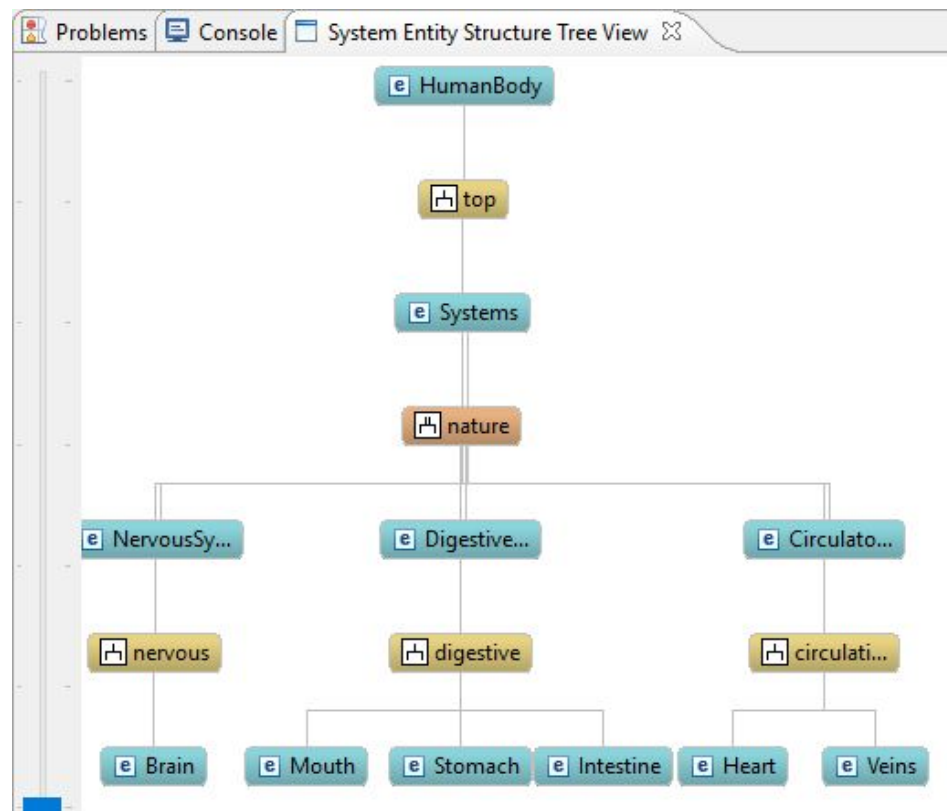
From the digestive perspective, DigestiveSystem is made of Mouth, Stomach, and Intestine!

From the circulation perspective, CirculatorySystem is made of Heart and Veins!



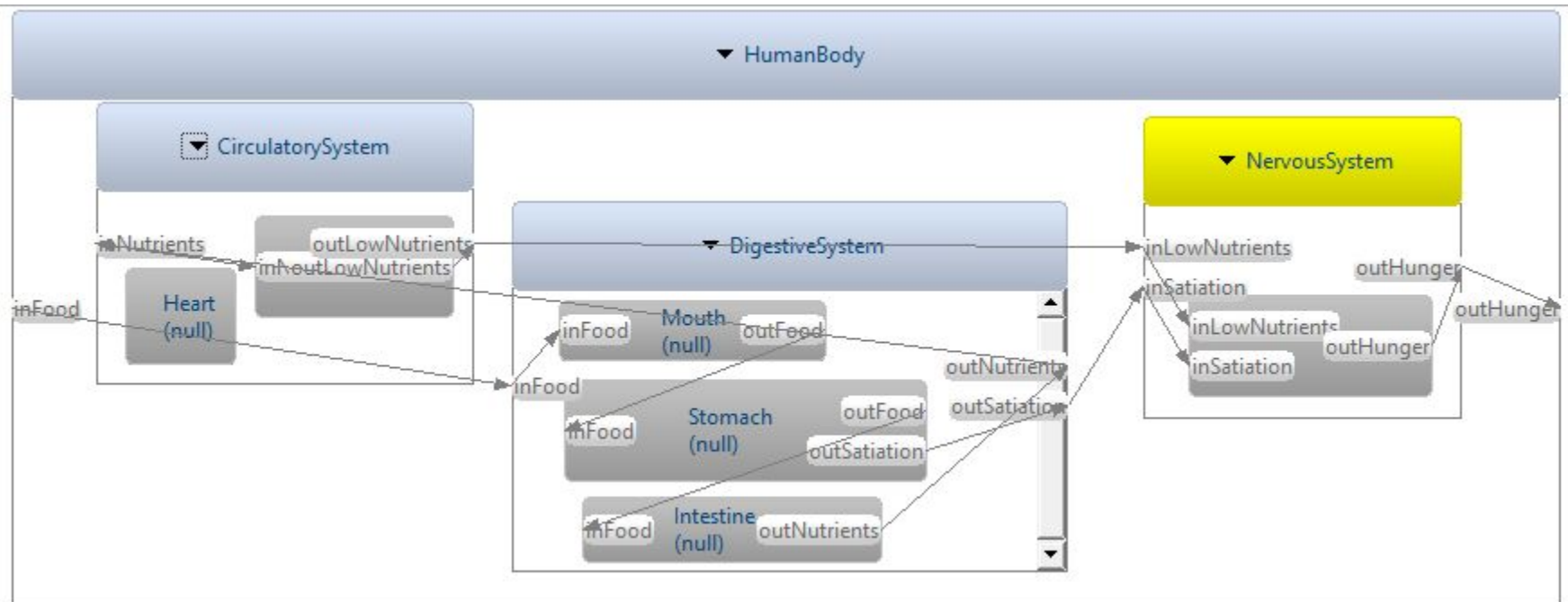
# DEVS Practice

- Changing Perspective (Hierarchical Construction)
  - Another perspective for the body (HumanBody.ses)



# DEVS Practice

- A “Simpler” one



# DEVS Practice

## A “simpler” one

From the top perspective, HumanBody is made of DigestiveSystem, CirculatorySystem, and NervousSystem!

//Makes it possible for the Food received in the DigestiveSystem to be sent to the mouth!

From the top perspective, HumanBody sends Food to DigestiveSystem!

From the digestive perspective, DigestiveSystem sends Food to Mouth!

//Body composition from different perspectives!

From the nervous perspective, NervousSystem is made of Brain!

From the digestive perspective, DigestiveSystem is made of Mouth, Stomach, and Intestine!

From the circulation perspective, CirculatorySystem is made of Heart and Veins!

From the digestive perspective, Mouth sends Food to Stomach!

From the digestive perspective, Stomach sends Food to Intestine!

From the digestive perspective, Stomach sends Satiation to DigestiveSystem!

From the digestive perspective, Intestine sends Nutrients to DigestiveSystem!

From the top perspective, DigestiveSystem sends Satiation to NervousSystem!

From the top perspective, DigestiveSystem sends Nutrients to CirculatorySystem!

From the circulation perspective, CirculatorySystem sends Nutrients to Veins!

From the circulation perspective, Veins sends LowNutrients to CirculatorySystem!

From the top perspective, CirculatorySystem sends LowNutrients to NervousSystem!

From the nervous perspective, NervousSystem sends LowNutrients to Brain!

From the nervous perspective, NervousSystem sends Satiation to Brain!

From the nervous perspective, Brain sends Hunger to NervousSystem!

From the top perspective, NervousSystem sends Hunger to HumanBody!

# Good Practices in DEVS (Conventions)



- 1) Atomic Models names should always start with uppercase letters;
- 2) Names of prospects (coupled models) always starting with lowercase;
- 3) Exclamation at the end of each statement, including in the comments.

# Exercise



- 1) Complete the Atomic Models code with Java Code to make the model executable.