

Modelling and Simulation

M&S for Software Engineering for M&S

Overview

1. What is Modelling and Simulation ?
2. The Modelling and Simulation Process + Example.
3. Rapid Application Development.
4. Hierarchy of System Specification, Systems Theory.
5. Classification of Models, Formalisms (model + simulator).
6. Untimed Discrete Event Formalisms:
 - (a) (Finite) State Automata.
 - (b) Adding Concurrency and Synchronisation: Petri Nets (cfr. UML).
 - (c) Adding Space: Cellular Automata.
 - (d) Adding Hierarchy and Orthogonality: State Charts (cfr. UML).

7. Timed Discrete Event Formalisms:

- (a) Timed Automata.
- (b) Event Scheduling.
- (c) Activity Scanning.
- (d) Three Phase Approach.
- (e) Process Interaction (GPSS).
- (f) DEVS.

8. Deterministic Simulation of Stochastic Processes:

Pseudo Random Number Generation.

9. Continuous Time Formalisms:

- (a) Ordinary Differential Equations & Algebraic Equations.
- (b) Differential Algebraic Equations.
- (c) CSSLs: sorting and algebraic loop detection.
- (d) Forrester System Dynamics, Population Dynamics.

- (e) Hybrid (continuous-discrete) modelling and simulation.
- (f) Non-causal modelling, Computer Algebra, Modelica.
- (g) Object-oriented Physical Systems Modelling: Bond Graphs.

What is Modelling and Simulation ?

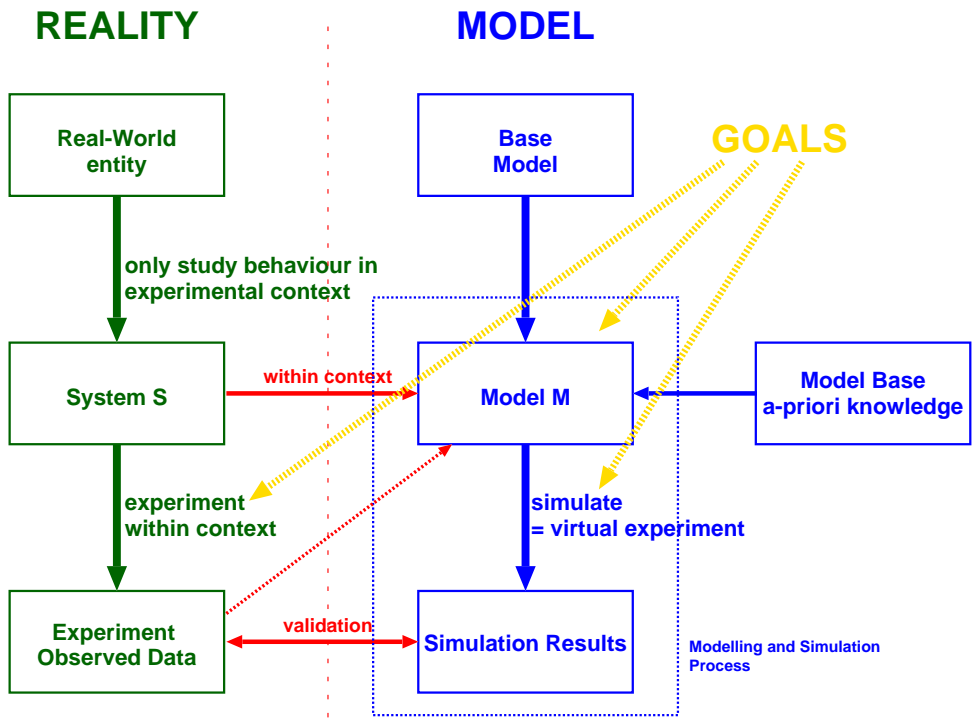
Why ?

- Modelling: represent/re-use/exchange knowledge about system structure and behaviour
- Simulation: to *emulate* real behaviour
 - cost, danger, . . .
 - what-if
 - optimization (do it right the first time)

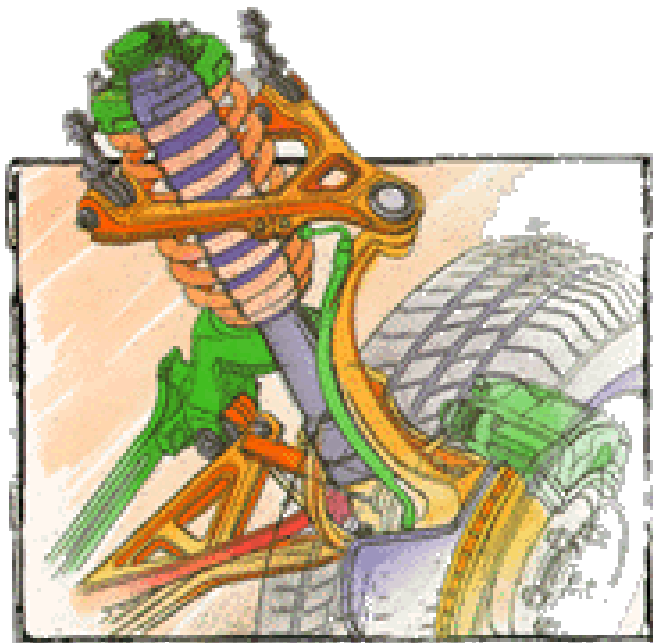
What ?

- . . . is Systems Theory, Control Theory
- . . . is Numerical Analysis, Symbolic Analysis
- . . . is Computer Science, Artificial Intelligence
- . . . is Operations Research
- . . . is Application Domain: Mechanical Engineering, . . .

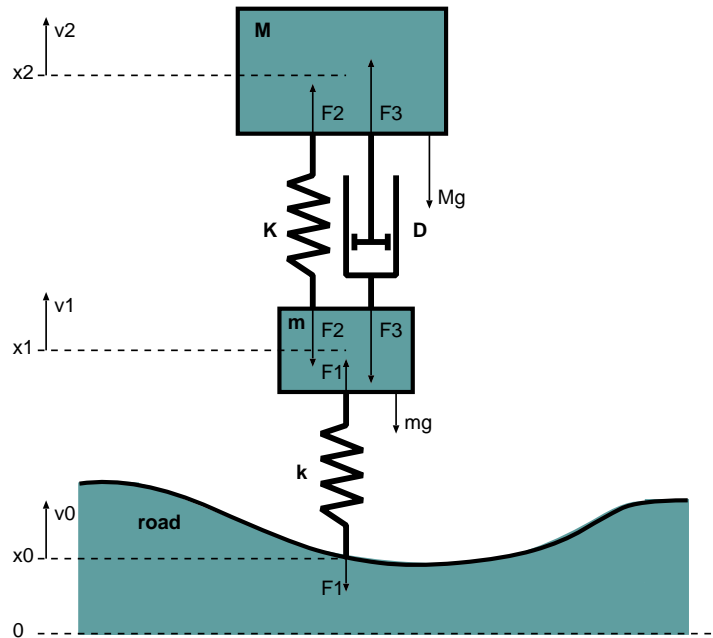
. . . or more GENERIC ?



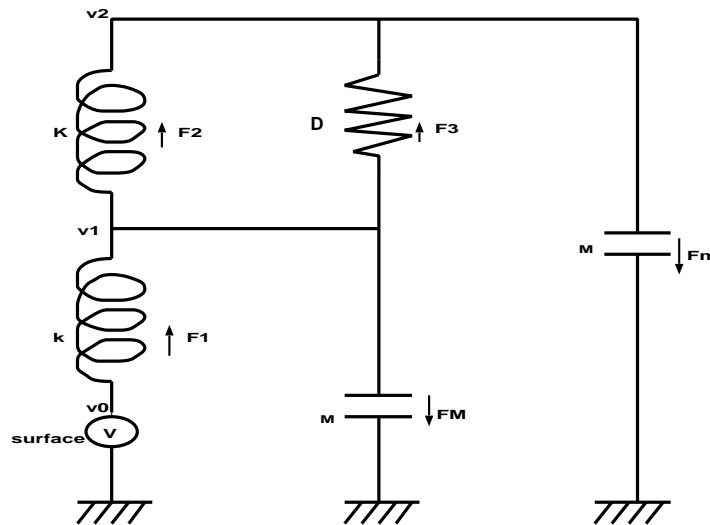
Multiple Formalisms: Physical



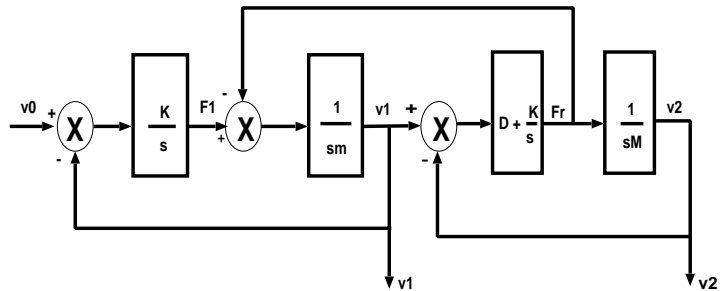
Multiple Formalisms: Mechanical



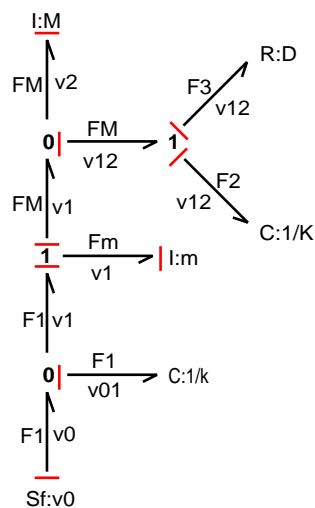
Multiple Formalisms: Electrical



Multiple Formalisms: Transfer Function



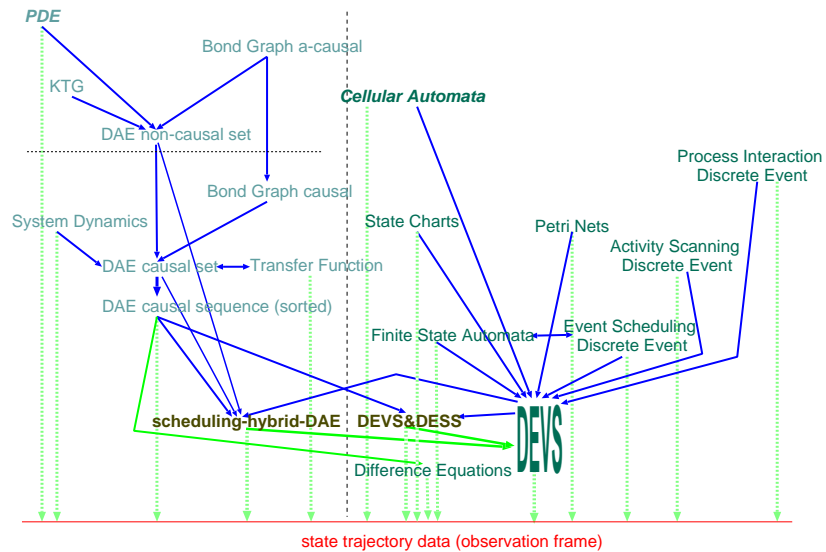
Multiple Formalisms: Bond Graph



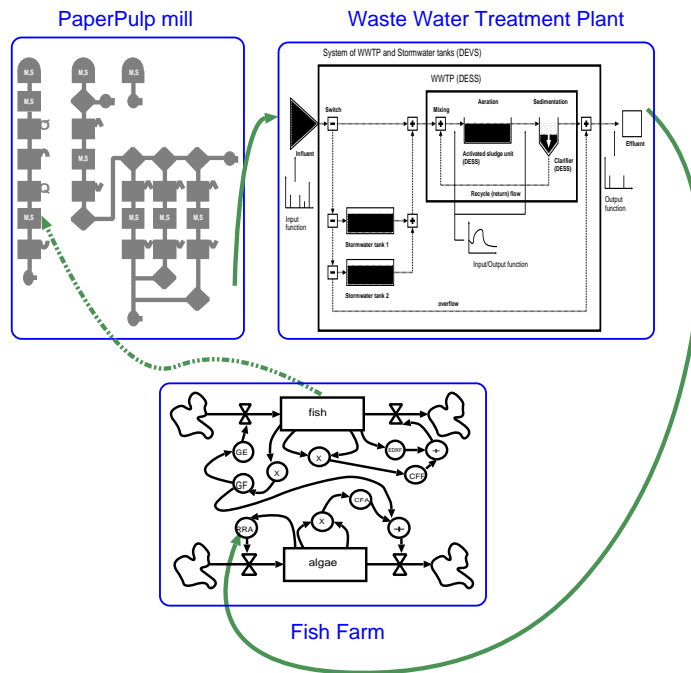
Multiple Formalisms: ODE

$$\begin{aligned}
 v_k &= v_0 - v_1 & F_3 &= v_D/D \\
 F_1 &= \frac{1}{k} \int v_k dt & v_K &= v_1 - v_2 \\
 F_m &= F_1 - F_2 - F_3 & F_2 &= \frac{1}{K} \int v_K dt \\
 v_1 &= \frac{1}{m} \int F_m dt & F_M &= F_2 + F_3 \\
 v_D &= v_1 - v_2 & v_2 &= \frac{1}{M} \int F_M dt
 \end{aligned}$$

Formalism transformation



Multi-formalism modelling



Process Interaction DEV: GPSS

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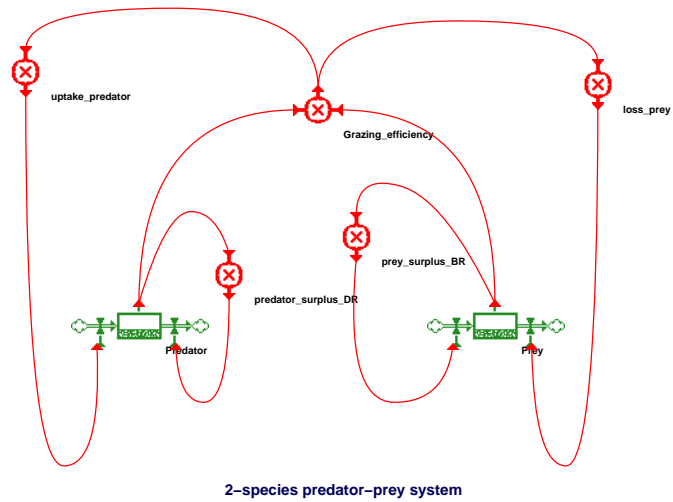
SIMULATE

*
* GPSS/H Block Section (the model)
*
*
*
* MANUFACTURING SHOP - MODEL 1
* Time unit = 1 minute
*
GENERATE 5      Create parts
ADVANCE  4,3    Inspect
TRANSFER .1,ACC,REJ Select rejects
ACC  TERMINATE 1 Accepted parts
REJ  TERMINATE 1 Rejected parts

*
* GPSS/H Control Statements (the experiment(s))
*
START 1000 Run 1000 parts

END
    
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Population Dynamics, System Dynamics



Trajectory

