CS 308-522A: Modelling and Simulation

M&S for Software Engineering for M&S . . .

Overview

1. What is Modelling and Simulation ?
2. Which topics does CS522 cover ?
3. How to get an A ?
4. What are the assignments about ?
5. Python ?
6. Where do I get the material covered in CS522 ?
7. Multiple formalisms ?

What is Modelling and Simulation ?

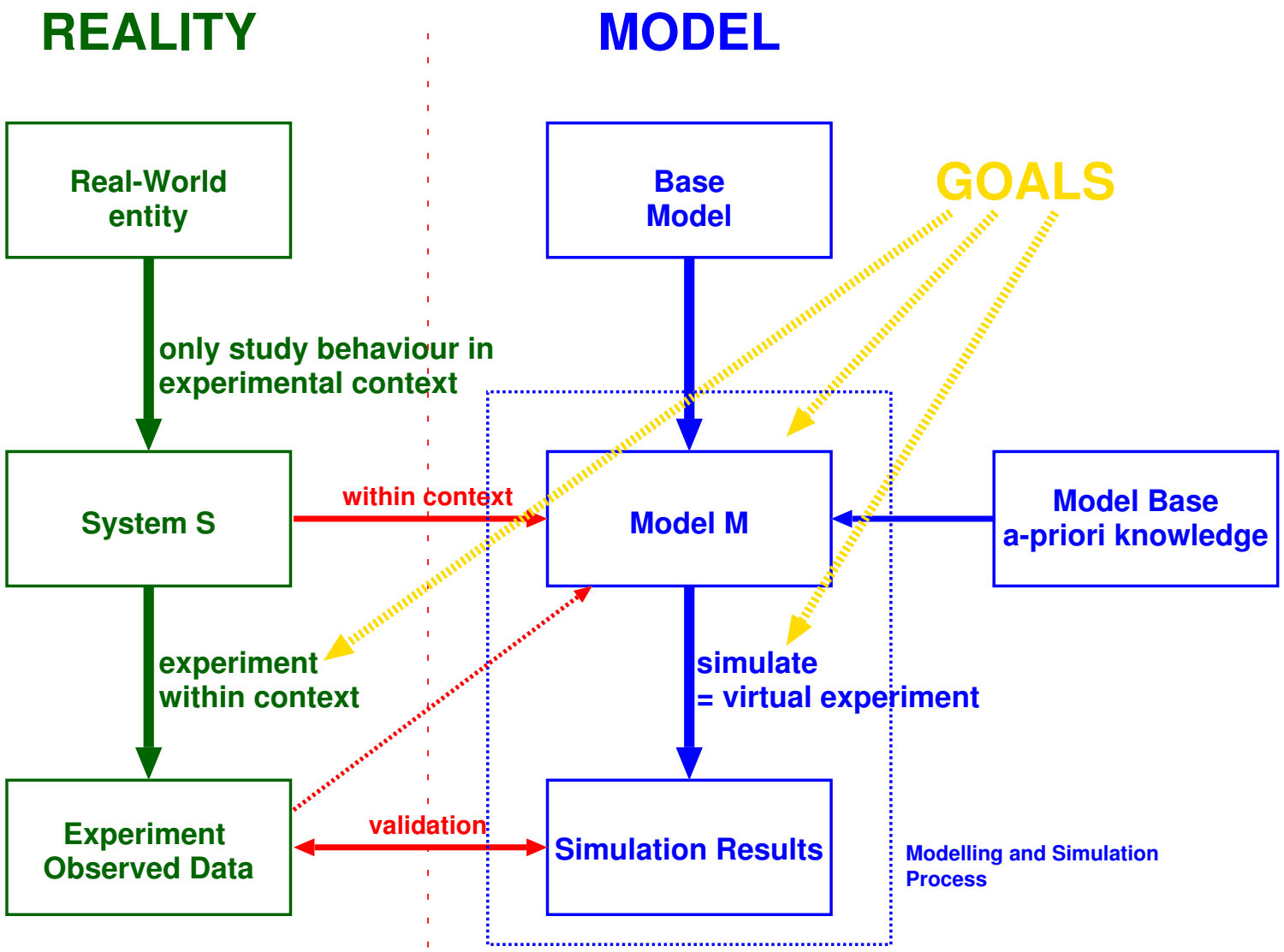
Why ?

- 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)

Modelling and Simulation . . .

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

. . . or more GENERIC ?


REALITY
MODEL
Real-World entity
Base Model
GOALS
only study behaviour in experimental context
System S
within context
Model M
Model Base a-priori knowledge
experiment within context
simulate = virtual experiment
Experiment Observed Data
validation
Simulation Results
Modelling and Simulation Process

Which topics does the course cover ?

1. Rapid Application Development with Python.
2. The Modelling and Simulation Process + Block Diagram example.
3. Hierarchy of System Specification, Systems Theory.
4. Classification of Models, Formalisms (model + simulator).
5. Untimed Discrete Event Formalisms:
   (a) (non)Deterministic State Automata.
   (b) Adding Concurrency and Synchronisation: Petri Nets (cfr. UML, specifying network protocols).
   (c) Adding Hierarchy and Orthogonality: State Charts (cfr. UML, specifying reactive software).
6. Timed Discrete Event Formalisms:

(a) Timed Automata.

(b) Event Scheduling (*e.g.,* parallel simulation of networks).

(c) Activity Scanning (AI).

(d) Three Phase Approach.

(e) Process Interaction (GPSS).

(f) DEVS as a rigourous basis for hierarchical modelling.

7. Deterministic Simulation of Stochastic Processes:

   (a) Pseudo Random Number Generation.

   (b) Gathering Statistics (performance metrics).

8. 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) Object-oriented Physical Systems Modelling: Non-causal modelling, Modelica.

How to get an A ?

- 30% on 5 (out of 6) highest scoring small assignments.
- 30% on 3 implementation assignments.
- 15% on the project.
- 25% on the final exam.

What are the small assignments about ?

1. Petri Net model for intersection/roundabout
2. State Chart model for CD player GUI
3. Process Interaction model for intersection/roundabout
4. GPSS assignments with simulator (+ ATOM3 GUI)
5. Modelica electrical system

What are the assignments involving coding about ?

(GUI behaviour should be modelled with State Charts)

1. Causal Block Diagram, Time Slicing simulator.
2. DEVS simulation of intersection/roundabout (2 styles) $+$ performance metrics $+$ animation.
3. Forrester System Dynamics model of Brooks' Law.

What are the project subjects ?

- GUI automatically generated from FSA specs
- Petri Net deadlock analysis
- Petri Net simulation environment with model animation.
- ES, AS simulators applied to cashier/queue.
- Process Interaction simulator applied to GPSS examples.
- Hybrid simulator applied to bouncing ball problem.
- Computer algebra: causality assignment and sorting.

Assignment rules of the game ?

- Completely on WWW: requirements, design, code, discussion.
- All coding in Python.
- In groups of max. 3 people (alone is feasible).
- Original work, present in class.
- Respect deadlines or do more work to compensate.

Python ?

- Why ?
- `www.python.org` Documentation/Tutorial.
- Tkinter tutorial this Friday at 16:45 in MC320.

Python scripting: Why ?

- purpose: glueing, system integration, *complimentary* to system programming languages.
- examples: command shells (sh, csh, zsh, . . .), Perl, Tcl, Python, Visual Basic, . . .
- Rapid Application Development (RAD):
  - interpreted (no edit/compile/link/test/. . .)
  - weak typing, but verbose and safe error diagnostics
  - garbage collected
  - powerful basic structures (control, dictionaries, exceptions, . . .)
  - classes are first class objects, introspection
- glue through extensions

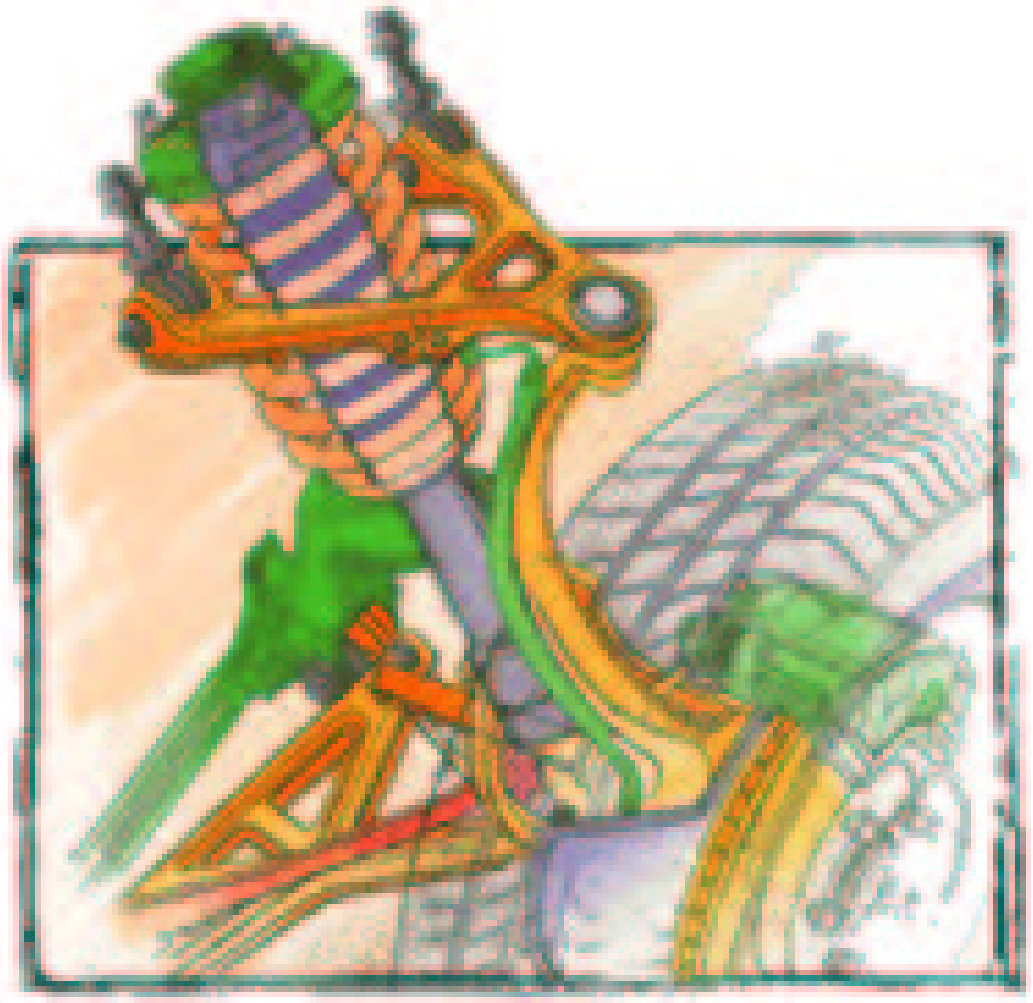
- embedding in large applications for user extension
- incremental development: dynamic loading (.so, .dll)
- platform-independent (Mac, Windows, UNIX)
- plethora of existing extensions (numerical, graphical (openGL, Tkinter), networks, . . .)

Where do I get the material covered in CS522 ?

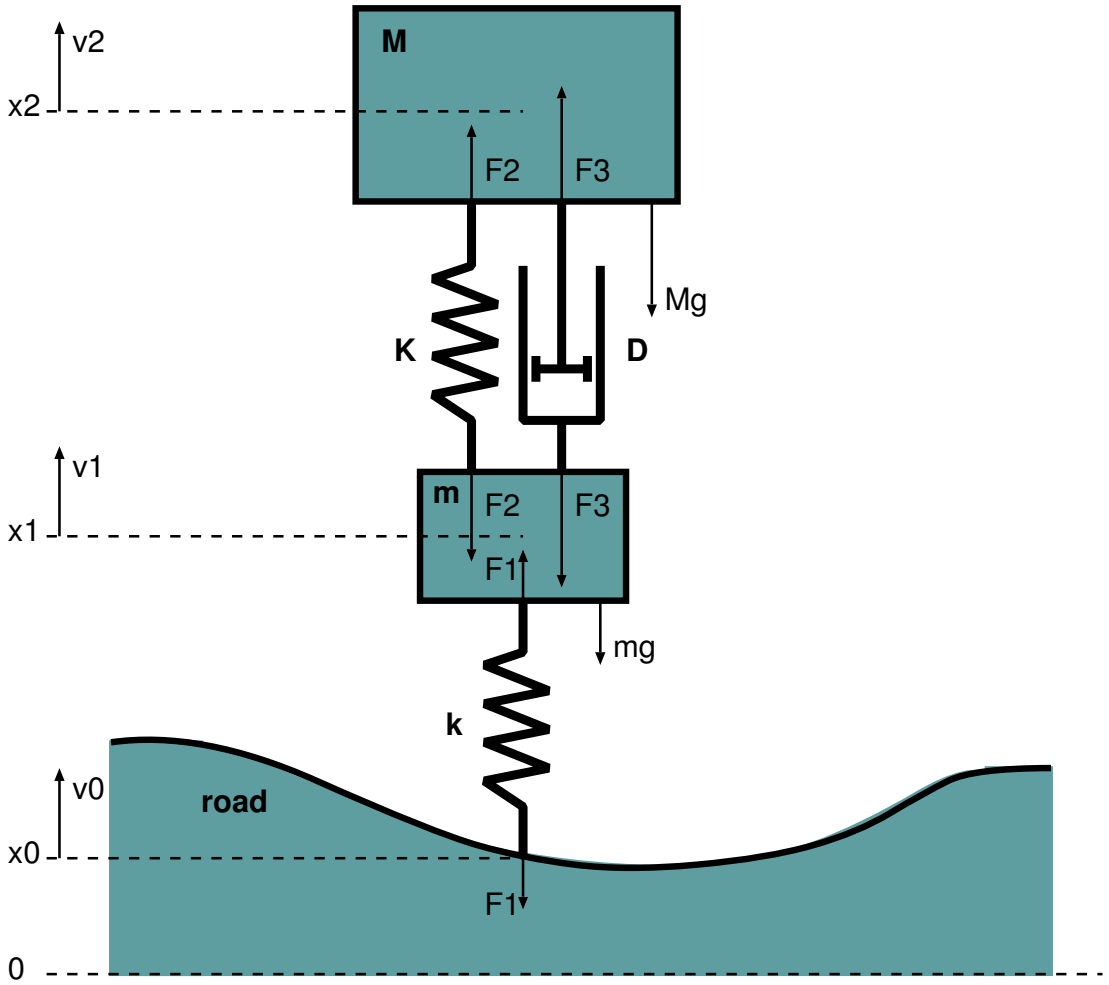
- Course pack covering the whole course.
- Class presentations online in PDF format.
- Links and references for those interested.

Multiple formalisms ? Car suspension

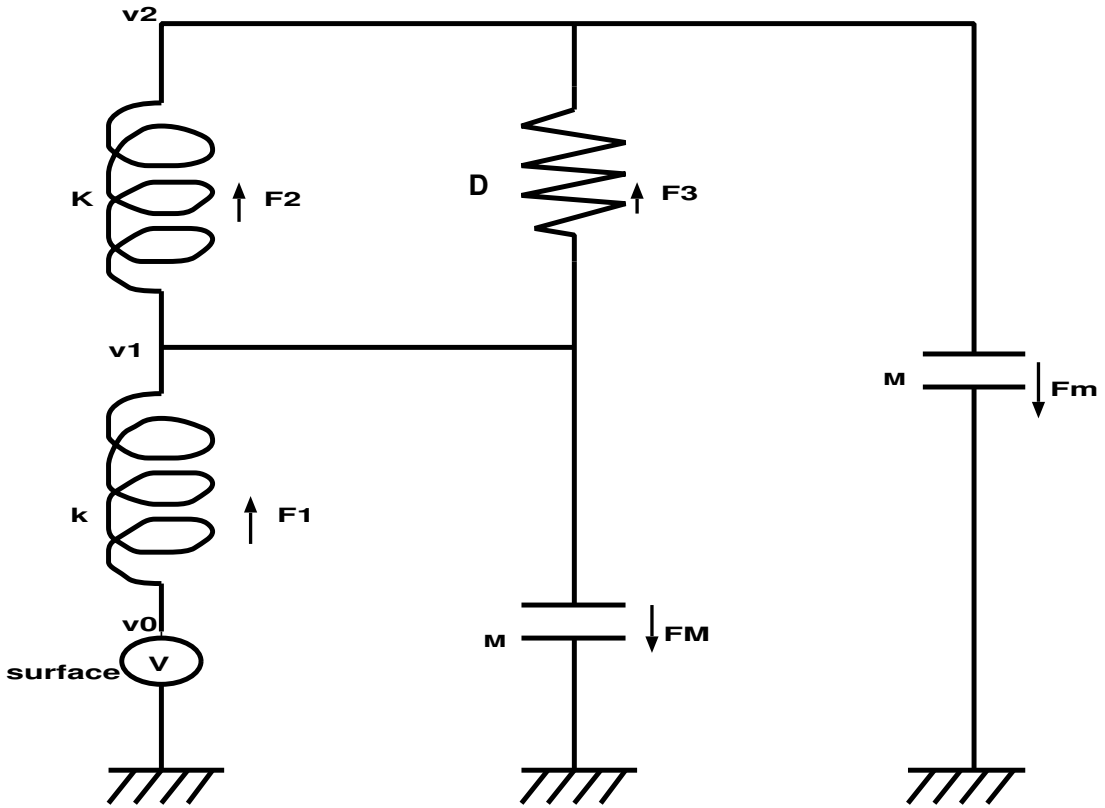
Multiple Formalisms: Physical



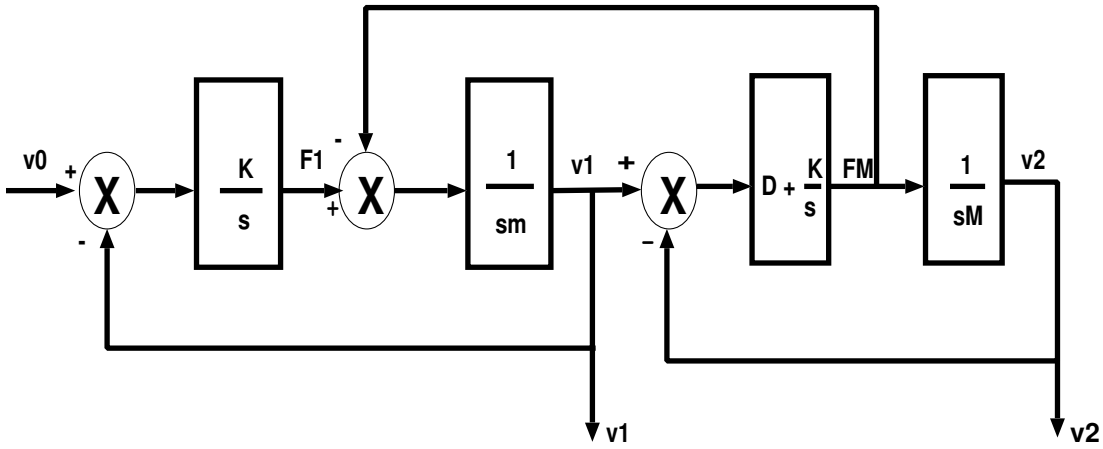
Multiple Formalisms: Mechanical



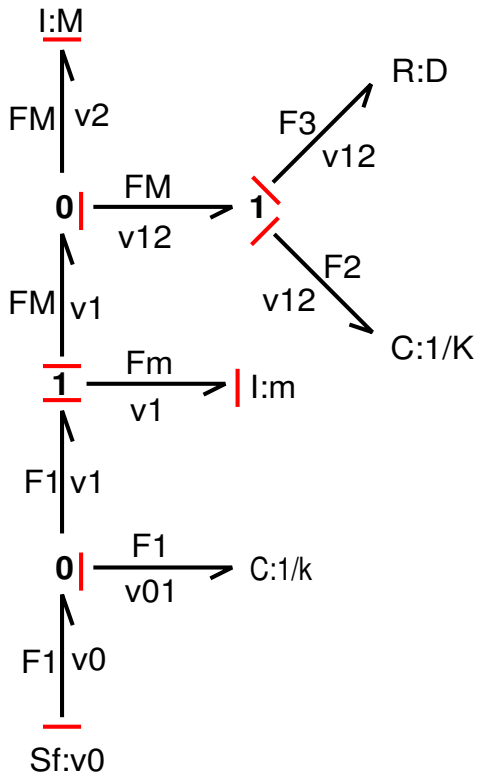
Multiple Formalisms: Electrical



Multiple Formalisms: Transfer Function



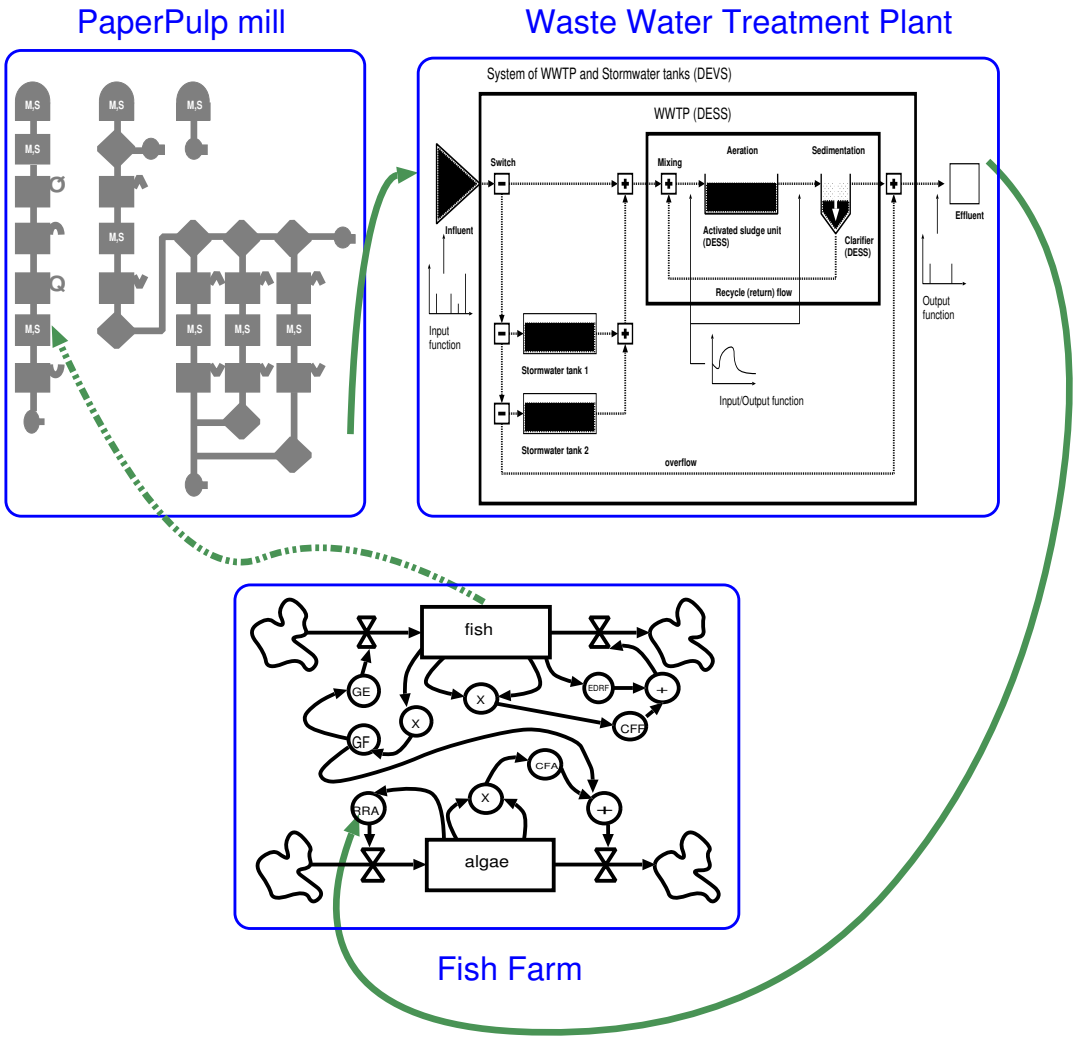
Multiple Formalisms: Bond Graph



Multiple Formalisms: ODE

$$
\begin{aligned}
v_k &= v_0 - v_1 & F_3 &= v_D/D \\
F_1 &= \tfrac{1}{k}\int v_k dt & v_K &= v_1 - v_2 \\
F_m &= F_1 - F_2 - F3 & F_2 &= \tfrac{1}{K}\int v_K dt \\
v_1 &= \tfrac{1}{m}\int F_m dt & F_M &= F_2 + F3 \\
v_D &= v_1 - v_2 & v_2 &= \tfrac{1}{M}\int F_M dt
\end{aligned}
$$

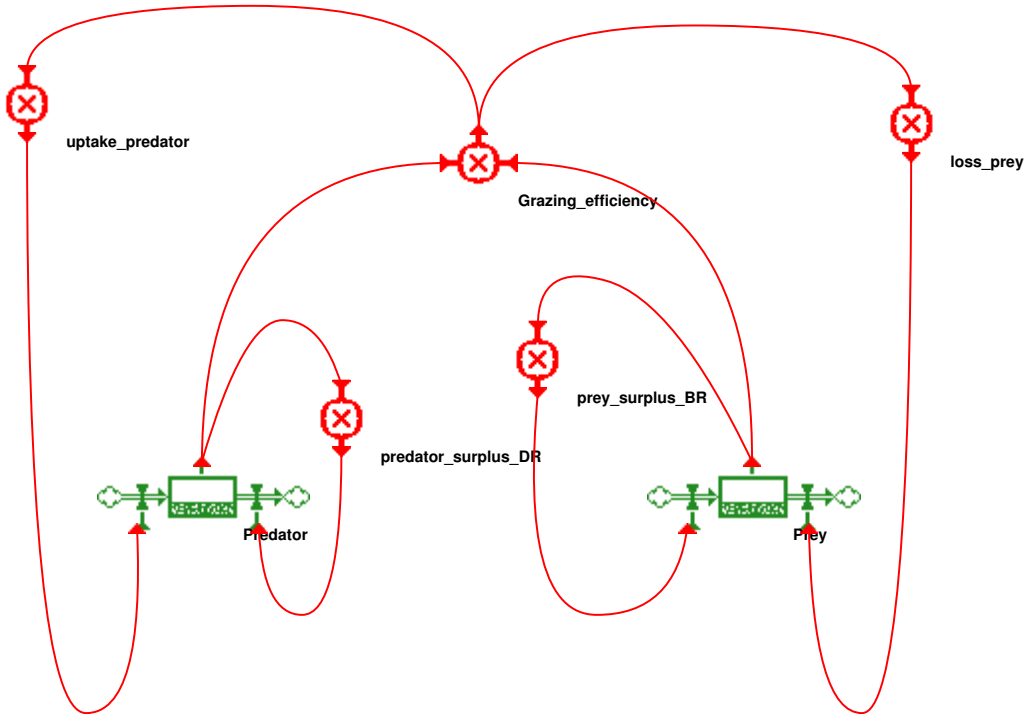
Multi-formalism modelling



Process Interaction DEV: GPSS

```
       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
```

Population Dynamics, System Dynamics



2–species predator–prey system

Trajectory