Modelling Languages

a short introduction

Hans Vangheluwe

http://msdl.cs.mcgill.ca/

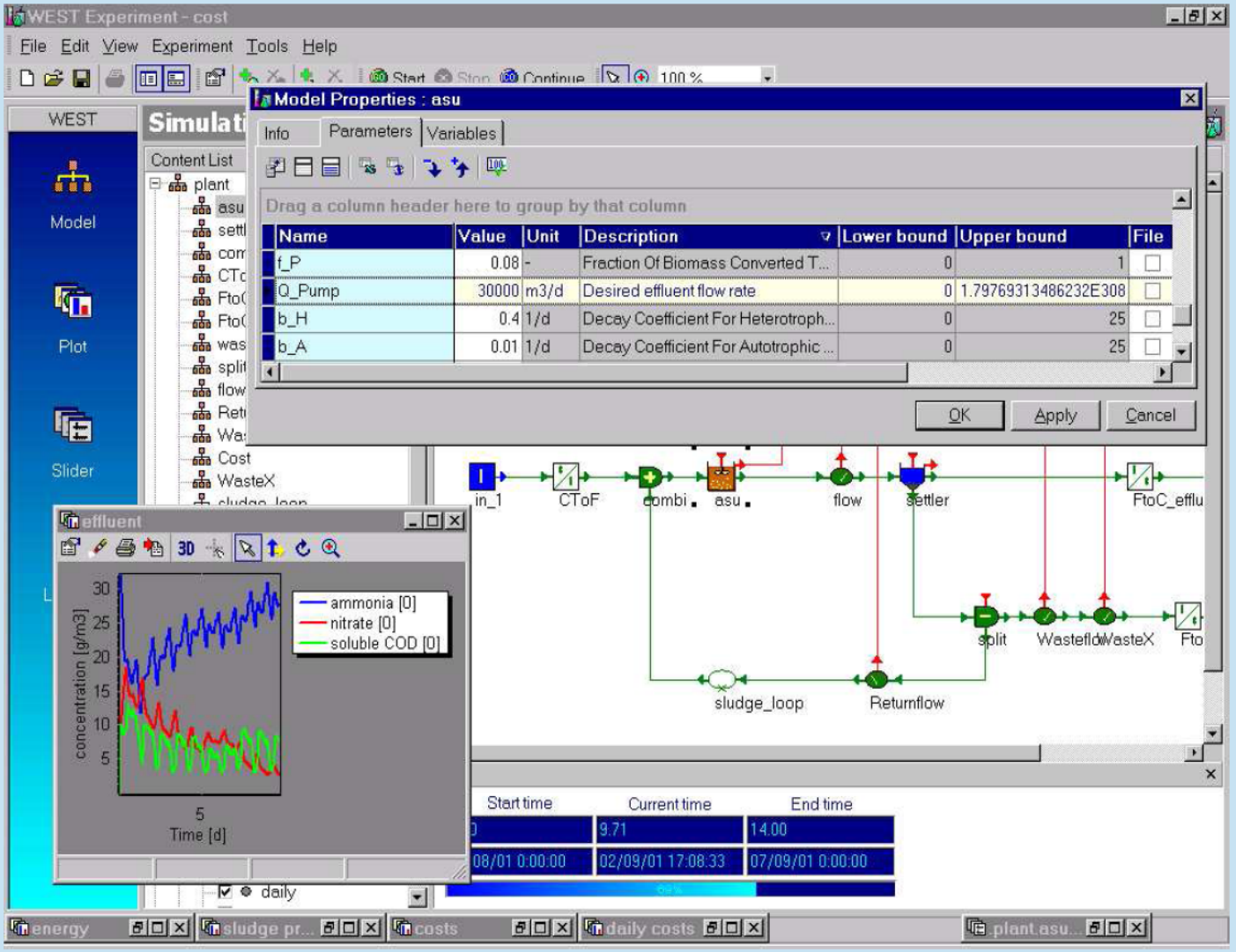
CUSO Winter School in Computer Science

Modelling of knowledge and the cyber-physical systems

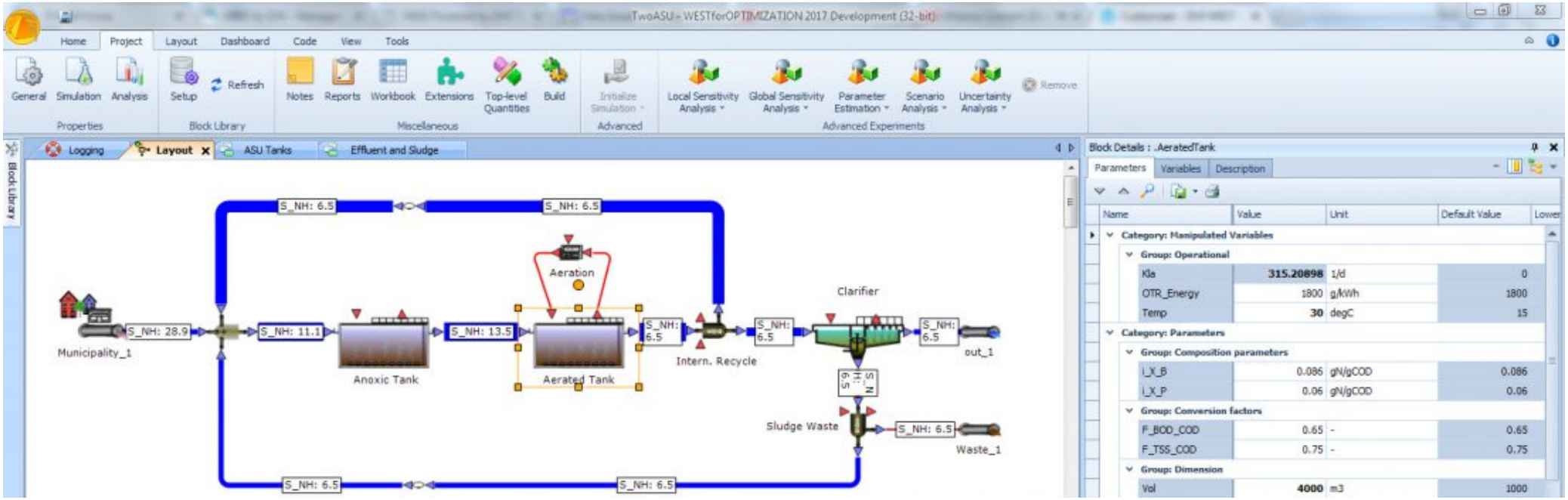
5 – 9 February 2018
Champéry, Switzerland

FLANDERS MAKE MANUFACTURING INNOVATION NETWORK
Universiteit Antwerpen
Nexor Cyber-Physical Systems University of Antwerp
Ansymo Antwerp Systems & Software Modelling University of Antwerp
McGill

DS(V)M Environment



WEST: modelling biological wastewater treatment.
Henk Vanhooren, Jurgen Meirlaen, Youri Amerlinck, Filip Claeys, Hans Vangheluwe and Peter A.Vanrolleghem.
Journal of Hydroinformatics 5 (2003) 27-50



http://www.mikebydhi.com/products/west

Syntax, **Semantics**, and all that Stuff

David Harel, Bernhard Rumpe.
Meaningful Modeling: What's the Semantics of "Semantics"?
IEEE Computer, vol. 37, no. 10, pp. 64-72, October, 2004.

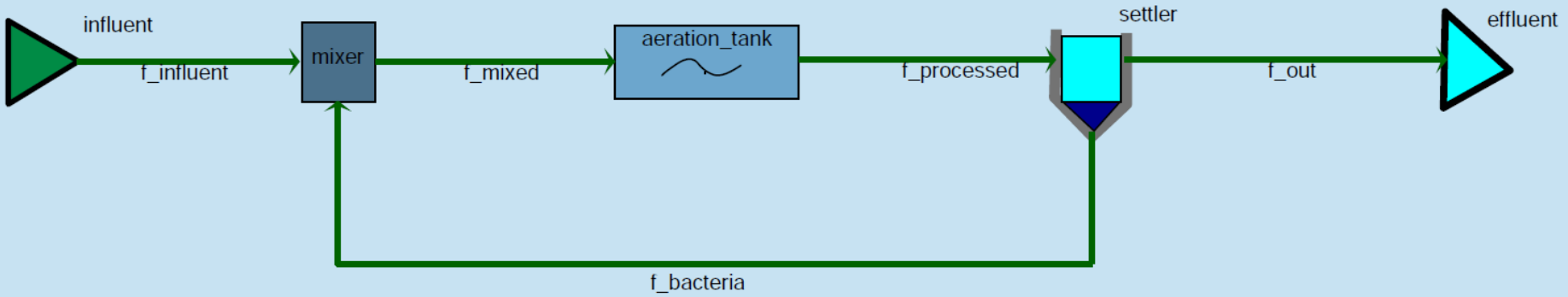
- "operational" semantics
- "denotational" (transformational) semantics

Operational vs. Denotational (Translational) semantics

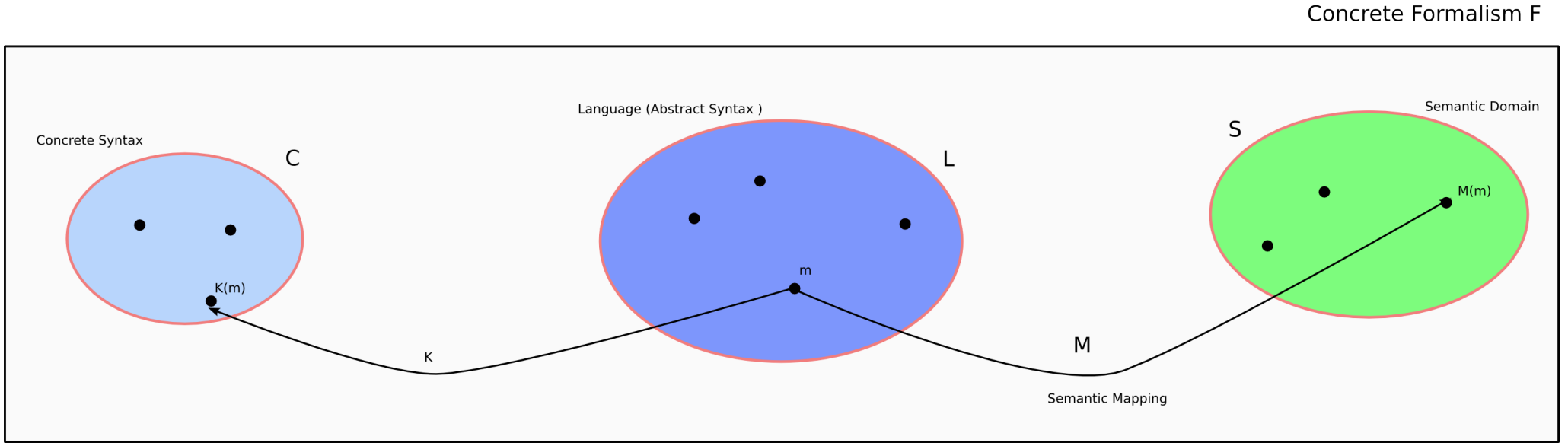
NATO's Sarajevo Waste Water Treatment Plant

www.nato.int/sfor/cimic/env-pro/waterpla.htm

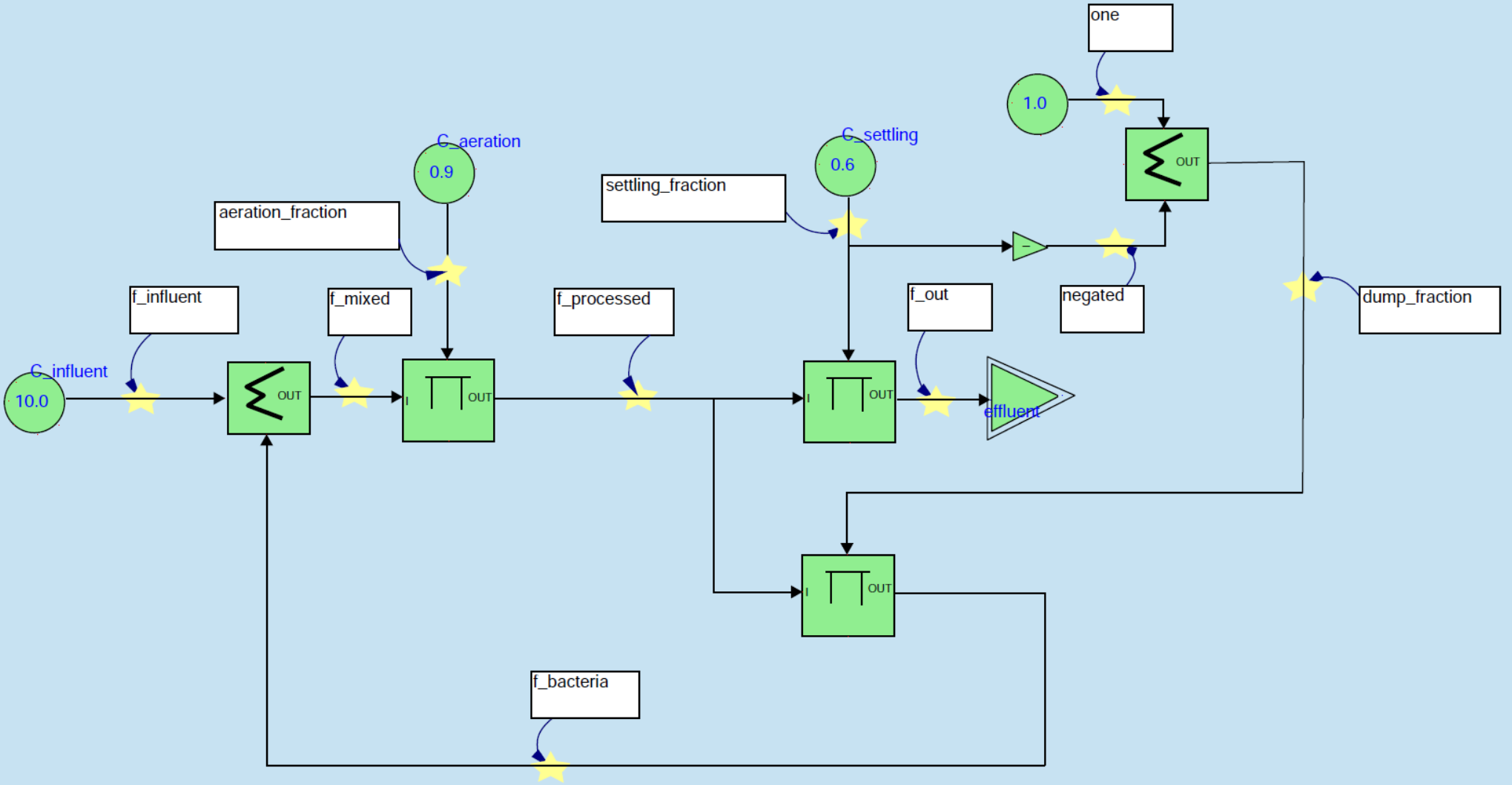
What does this WWTP model mean?



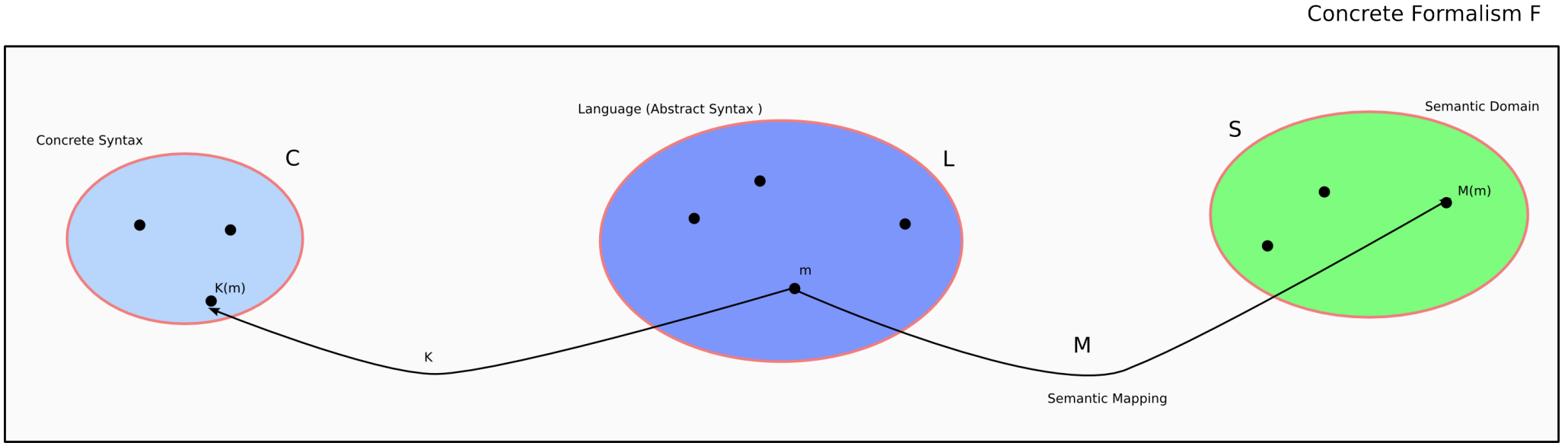
“linguistic” view on Modelling Languages/Formalisms: Syntax and Semantics



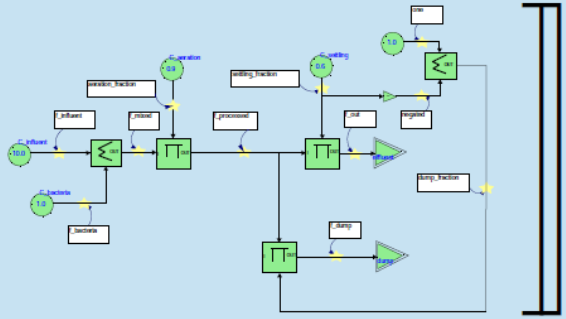
. . . its meaning (steady-state abstraction): Causal Block Diagram (CBD)



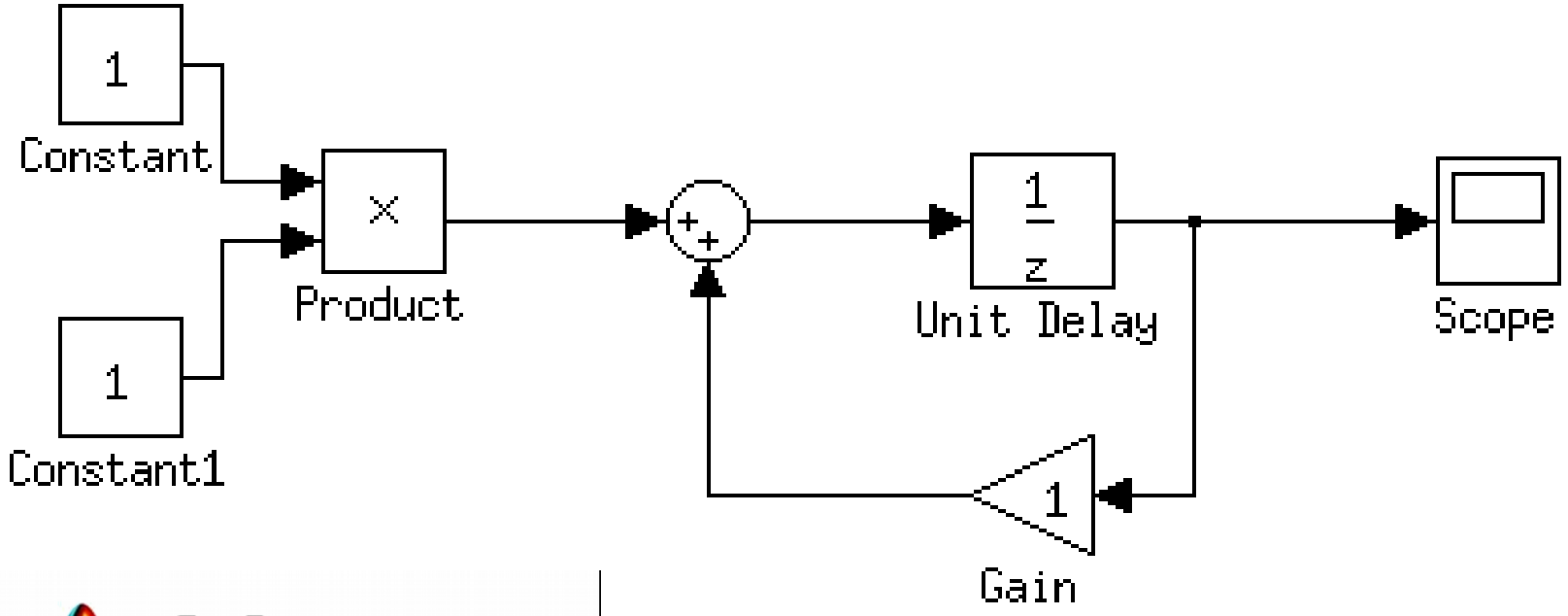
“linguistic” view on Modelling Languages/Formalisms: Syntax and Semantics



Meaning of the CBD . . . semantic mapping onto algEqns

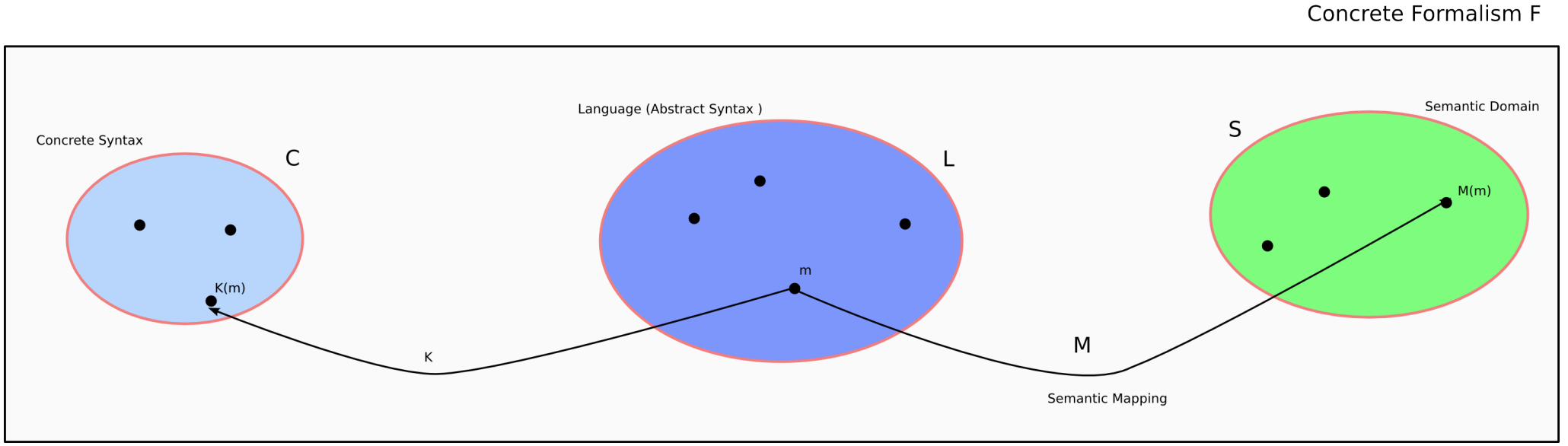
$$[\![\ \text{  }\ ]\!] = \left\{ \begin{array}{rcl} f\_influent & = & C\_influent \\ f\_bacteria & = & C\_bacteria \\ f\_mixed & = & f\_influent + f\_bacteria \\ aeration\_fraction & = & C\_aeration \\ f\_processed & = & aeration\_fraction * f\_mixed \\ settling\_fraction & = & C\_settling \\ negated & = & -settling\_fraction \\ one & = & 1 \\ dump\_fraction & = & one + negated \\ f\_dump & = & f\_processed * dump\_fraction \\ f\_out & = & settling\_fraction * f\_processed \end{array} \right.$$

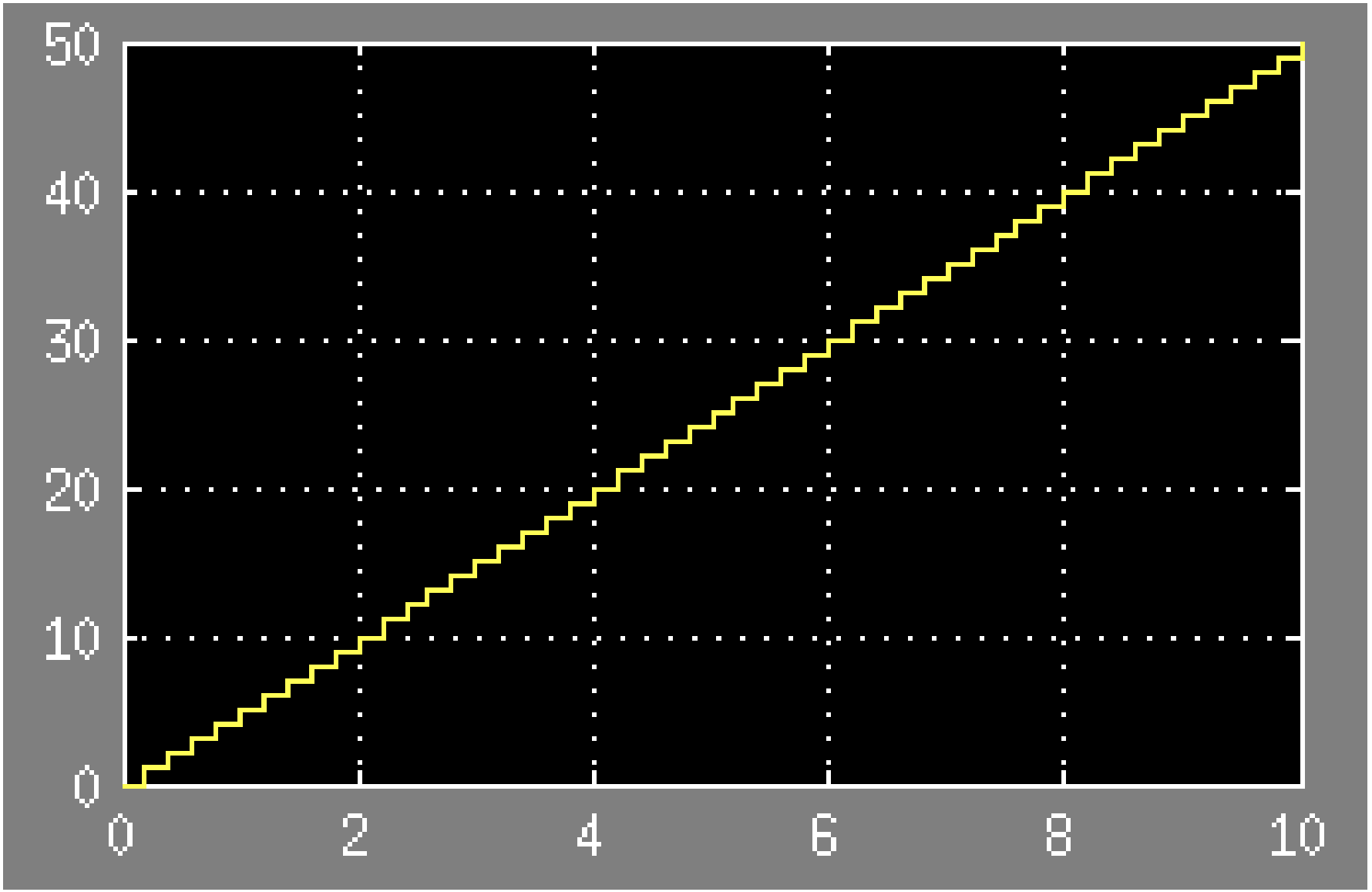
Causal Block Diagrams (syntax)



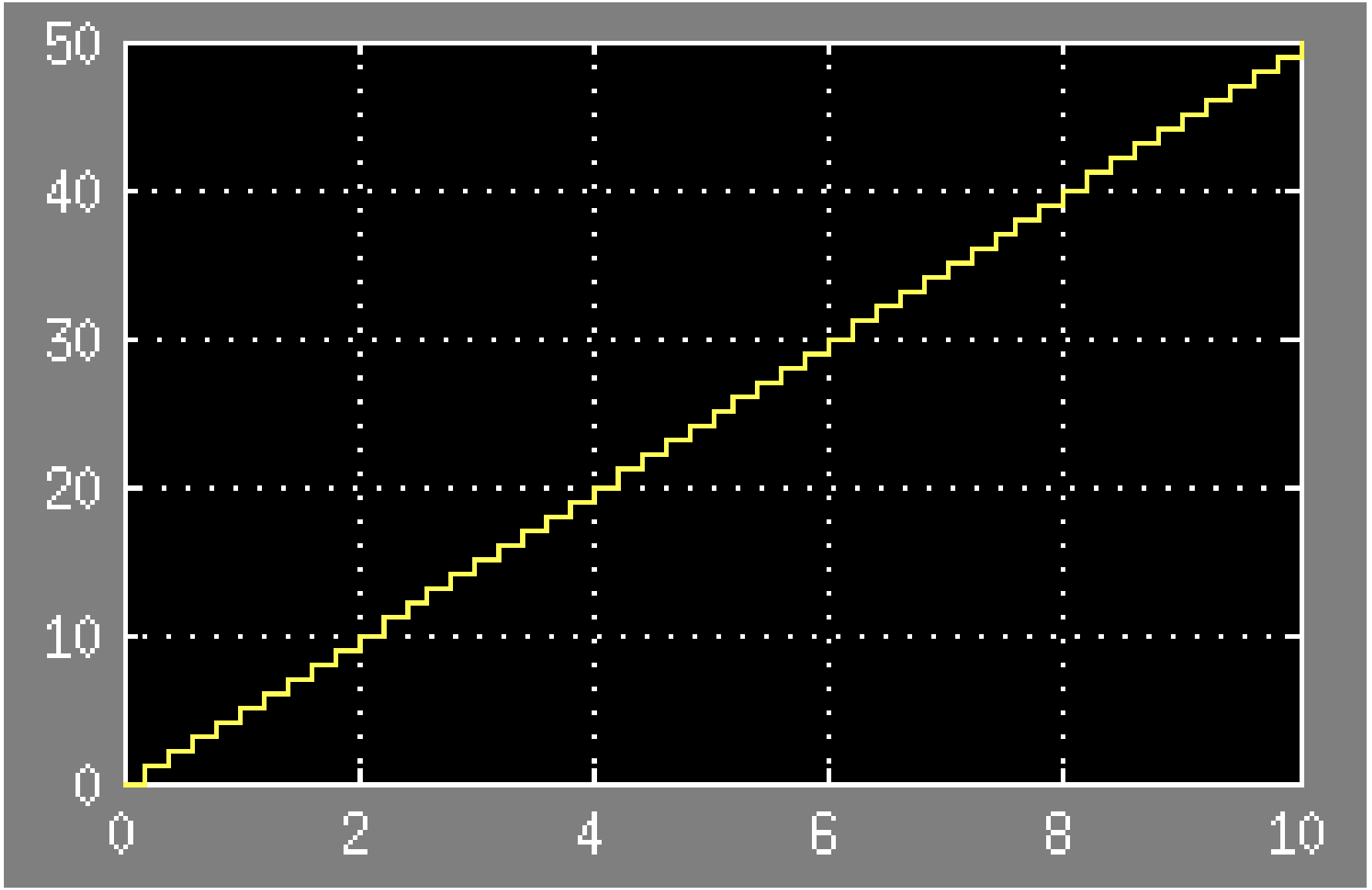
MATLAB®
SIMULINK®

“linguistic” view on Modelling Languages/Formalisms: Syntax and Semantics




50
40
30
20
10
0
0
2
4
6
8
10

$logicalTime \leftarrow 0$
while not end_condition **do**
    $schedule \leftarrow LOOPDETECT(DEPGRAPH(cbd))$
    for gblock **in** schedule **do**
        $COMPUTE(gblock)$
    end for
    $logicalTime \leftarrow logicalTime + \Delta t$
end while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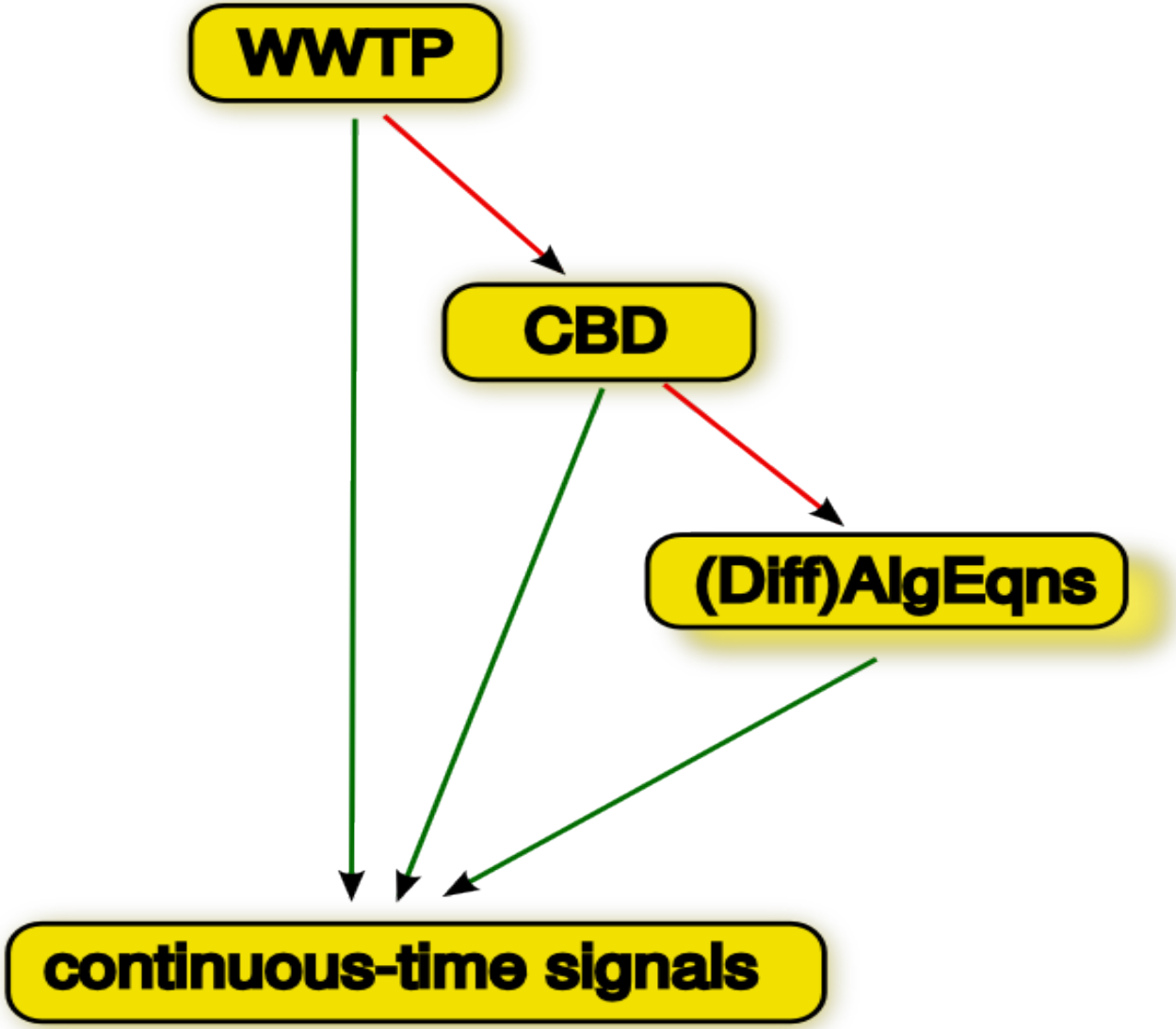
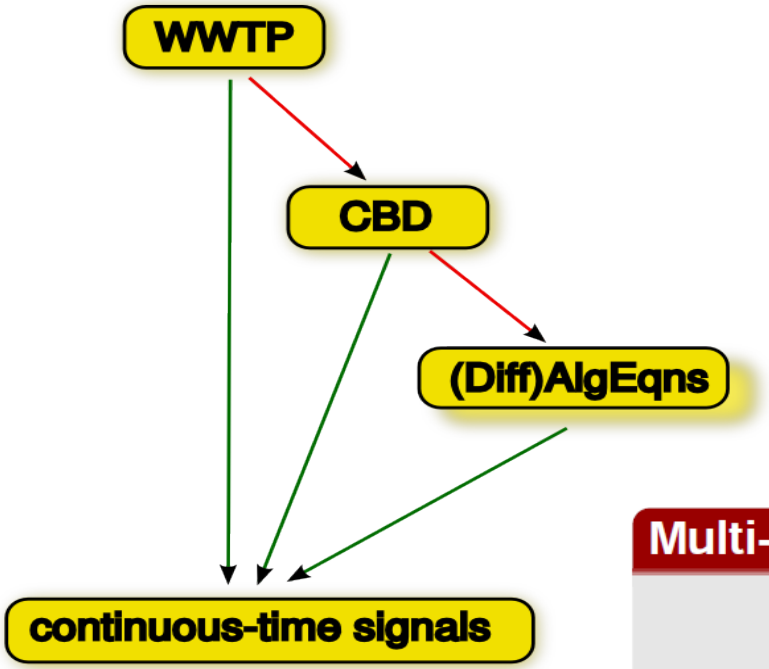

WWTP
CBD
(Diff)AlgEqns
continuous-time signals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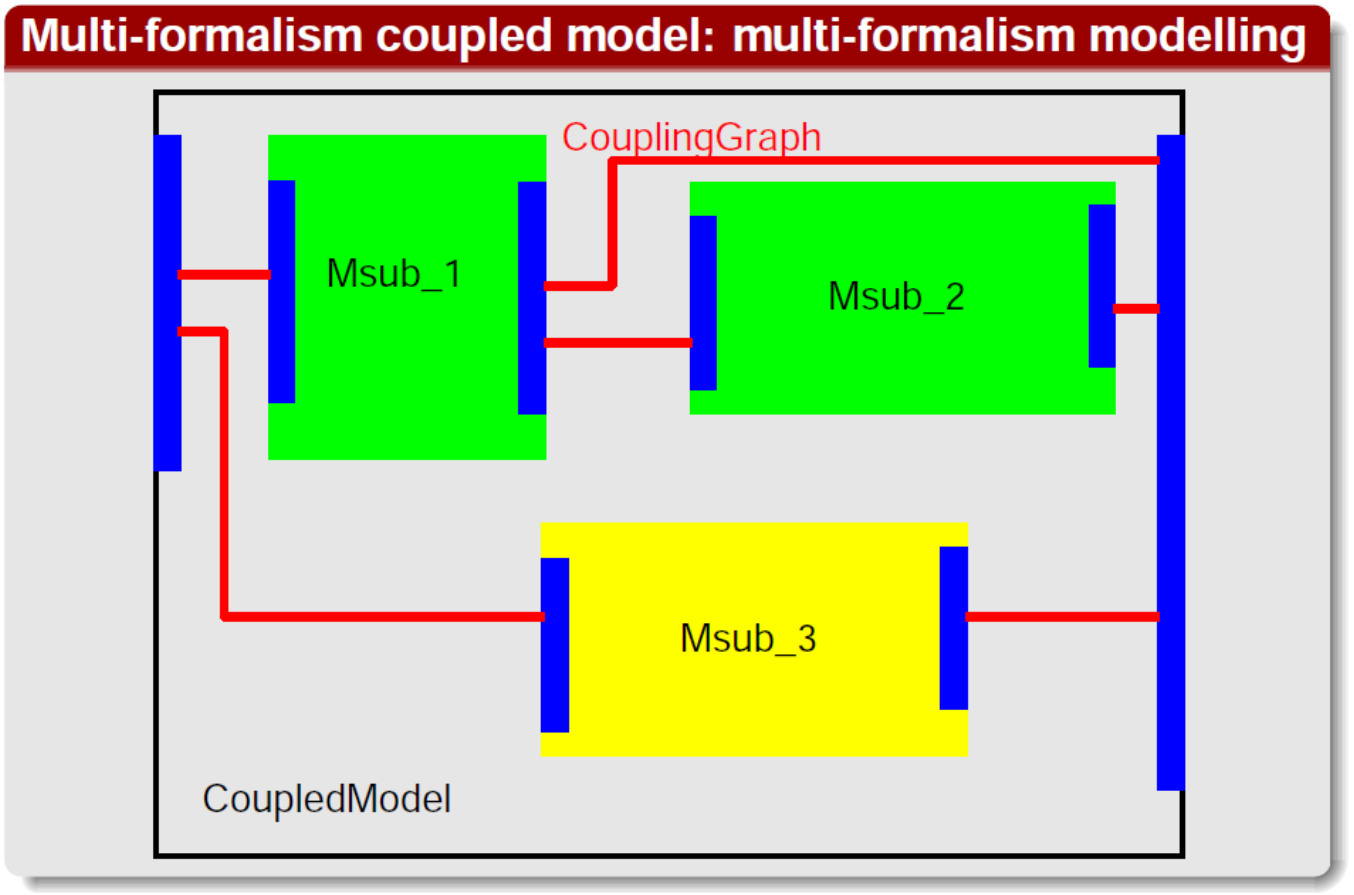
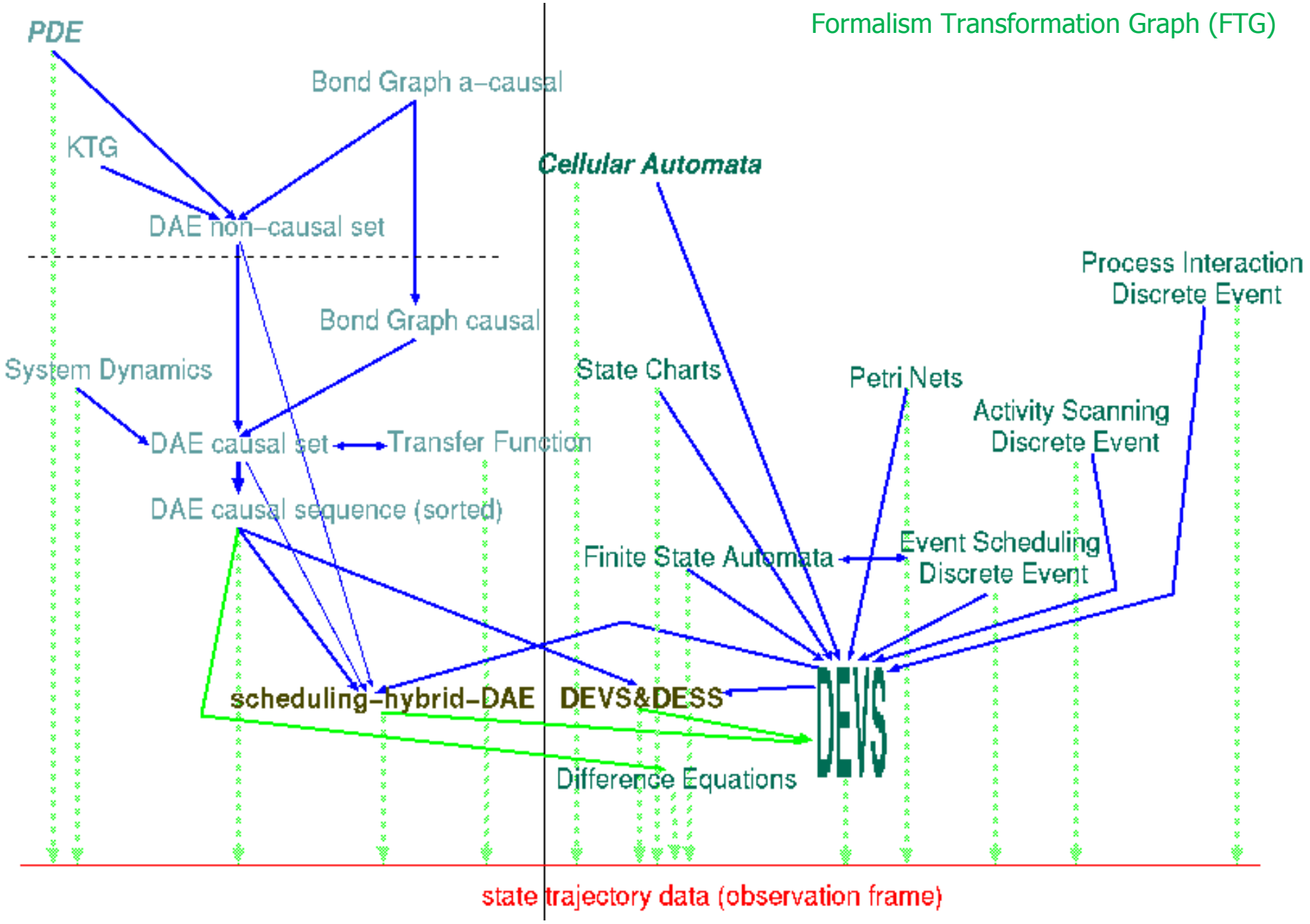
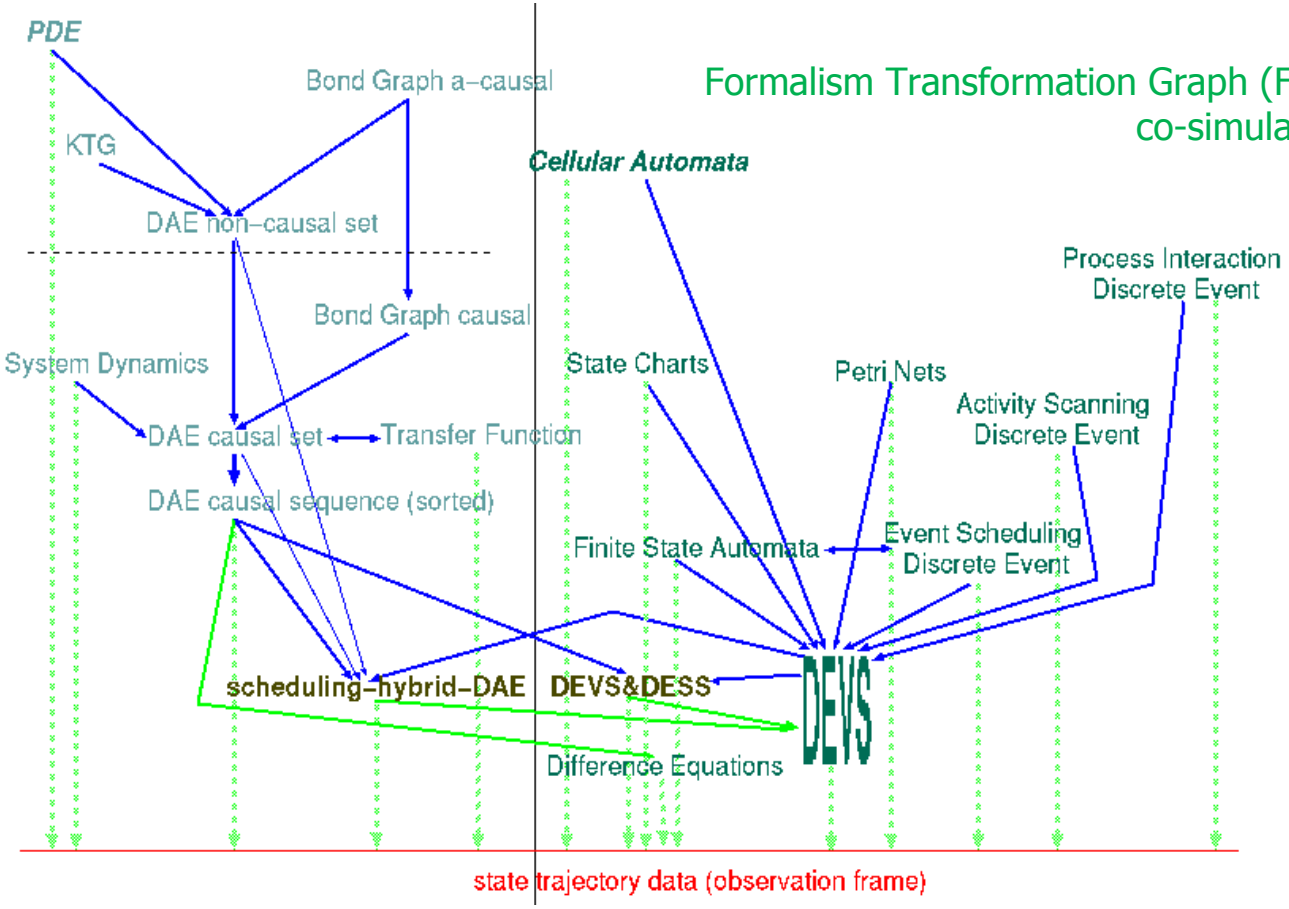

Multi-formalism coupled model: multi-formalism modelling
CouplingGraph
Msub_1
Msub_2
Msub_3
CoupledModel

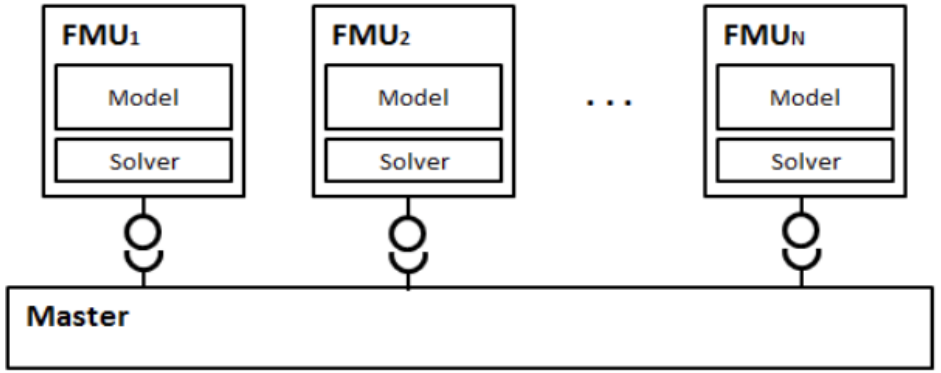


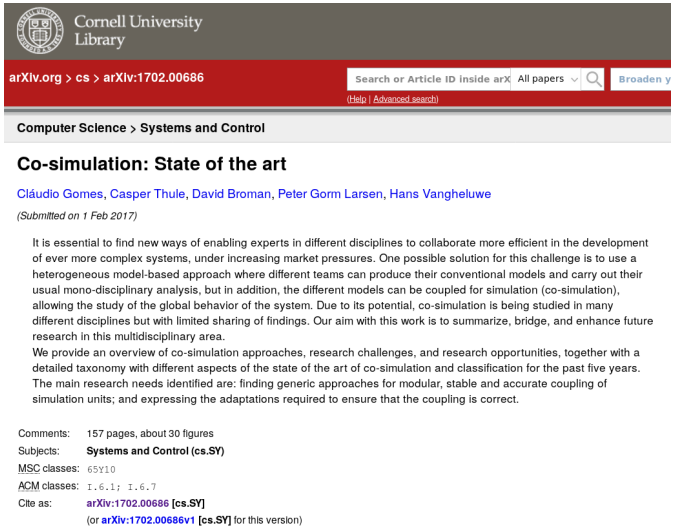
Hans Vangheluwe and Ghislain C. Vansteenkiste. A multi-paradigm modeling and simulation methodology: Formalisms and languages. In European Simulation Symposium (ESS) , pages 168 – 172. Society for Computer Simulation International (SCS), October 1996. Genoa, Italy.



Formalism Transformation Graph (FTG) co-simulation

FUNCTIONAL MOCK-UP INTERFACE




Cornell University Library

arXiv.org > cs > arXiv:1702.00686

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Computer Science > Systems and Control

Co-simulation: State of the art

Cláudio Gomes, Casper Thule, David Broman, Peter Gorm Larsen, Hans Vangheluwe

(Submitted on 1 Feb 2017)

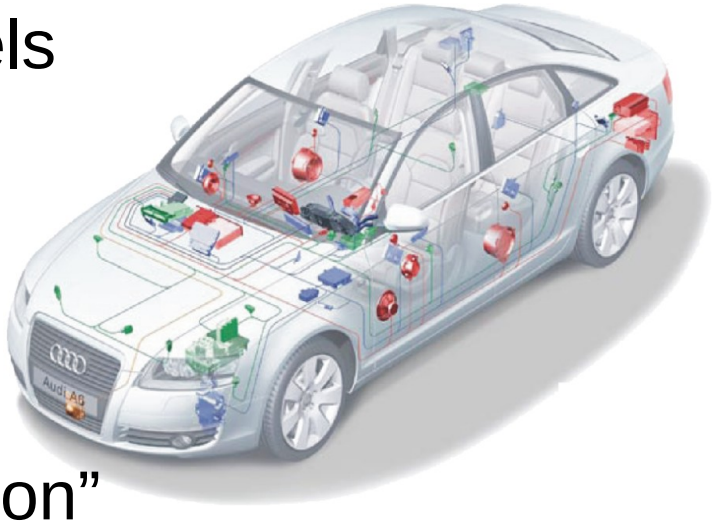
It is essential to find new ways of enabling experts in different disciplines to collaborate more efficient in the development of ever more complex systems, under increasing market pressures. One possible solution for this challenge is to use a heterogeneous model-based approach where different teams can produce their conventional models and carry out their usual mono-disciplinary analysis, but in addition, the different models can be coupled for simulation (co-simulation), allowing the study of the global behavior of the system. Due to its potential, co-simulation is being studied in many different disciplines but with limited sharing of findings. Our aim with this work is to summarize, bridge, and enhance future research in this multidisciplinary area.
We provide an overview of co-simulation approaches, research challenges, and research opportunities, together with a detailed taxonomy with different aspects of the state of the art of co-simulation and classification for the past five years. The main research needs identified are: finding generic approaches for modular, stable and accurate coupling of simulation units; and expressing the adaptations required to ensure that the coupling is correct.

Comments: 157 pages, about 30 figures
Subjects: **Systems and Control (cs.SY)**
MSC classes: 65Y10
ACM classes: I.6.1; I.6.7
Cite as: arXiv:1702.00686 [cs.SY]
(or arXiv:1702.00686v1 [cs.SY] for this version)

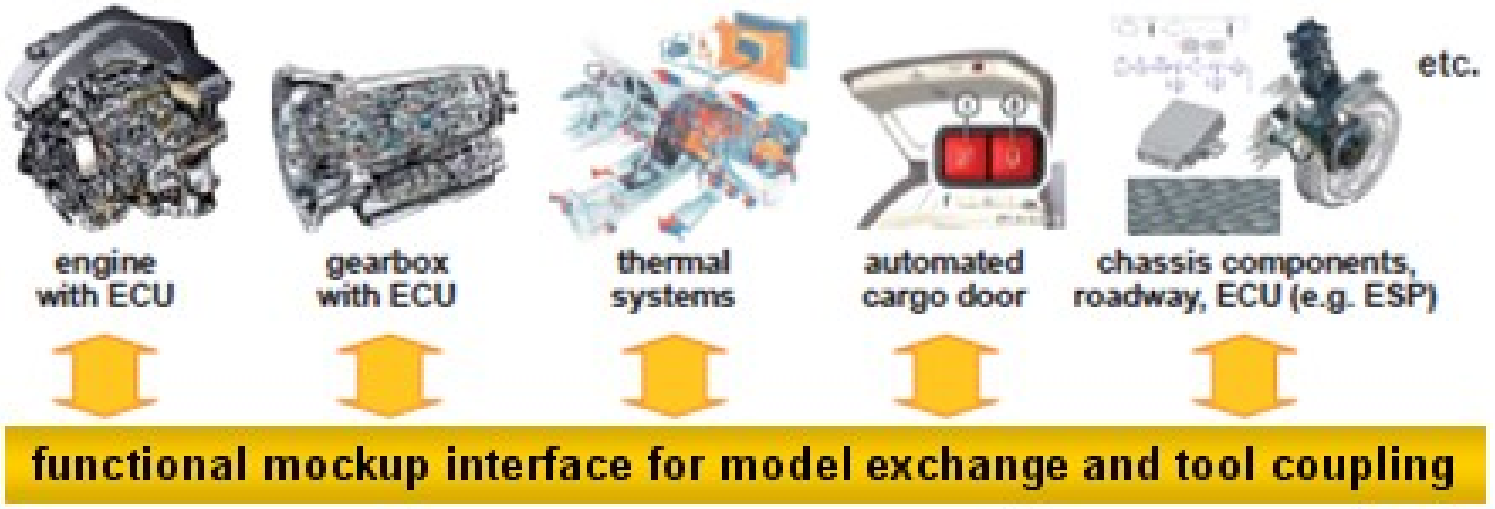
Cláudio Gomes, Casper Thule, David Broman, Peter Gorm Larsen, Hans Vangheluwe. Co-simulation: State of the art. ArXiv 1702.00686. 2017.

Functional Mock-up Interface (FMI)

- **XML** + Binary Representation for Models
  - Standard
  - Modelling Tool Independent
  - +/- Black box …



- Composed FMUs still need “orchestration”



www.fmi-standard.org

Explicit "linguistic" Modelling of Modelling Languages/Formalisms