E3S
Supelec
Systems
Science

Supélec

Heterogeneous Systems and Multi-Paradigm Modeling

ModHel'X

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Who are we?

- Supélec = leading engineering school ("Grande Ecole") in information sciences and energy
  - Degree courses: 460 students graduating each year (engineering diploma)
  - Continuing education
  - Research & development: Supélec Systems Science (E3S) (automatic control, signal processing, radio communications, electromagnetism, power systems, computer science)

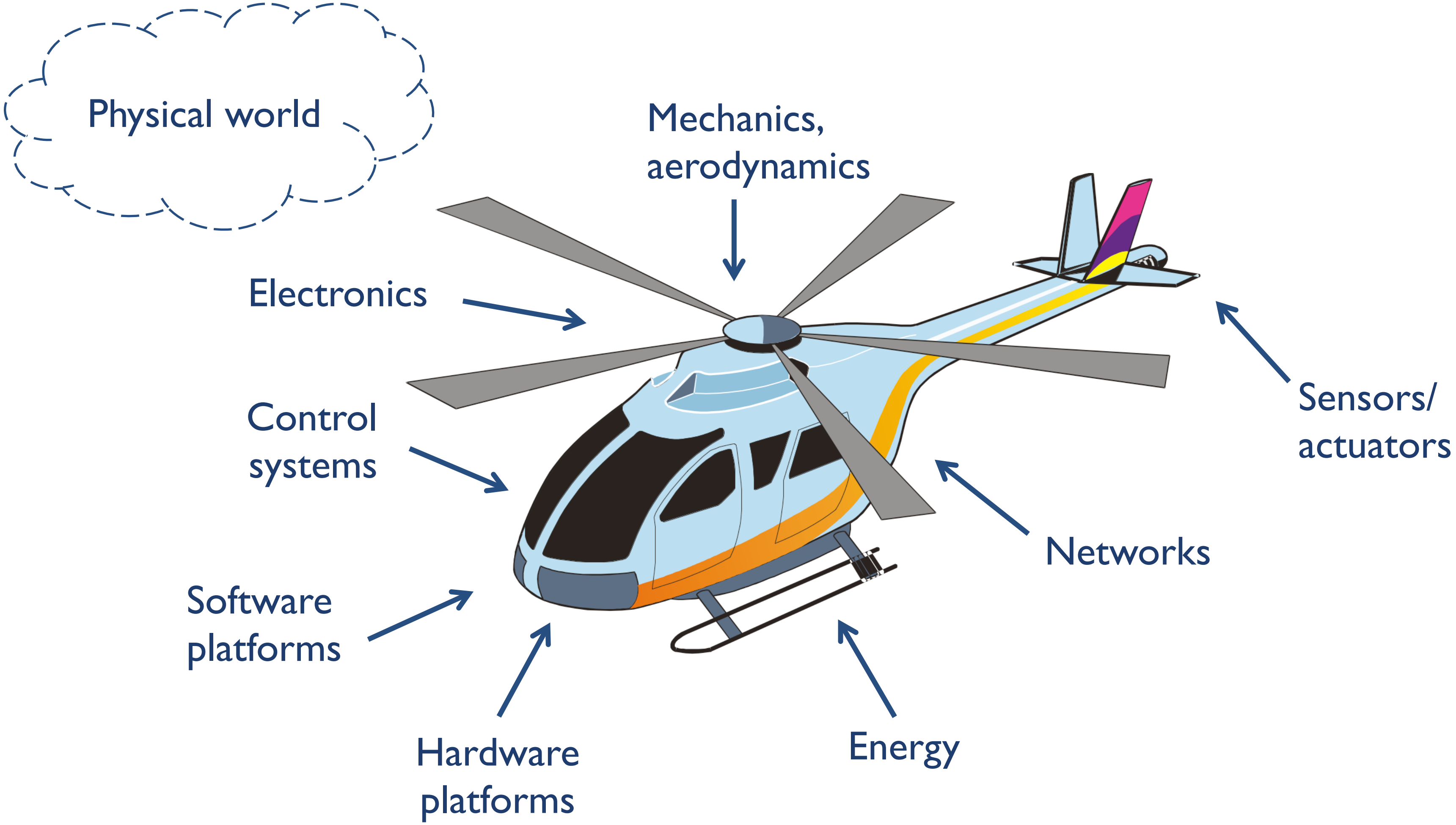
- Department of Computer Science = research & education department
  - Personalization: adaptive hypermedia, guided web queries (4 + 4 PhD students)
  - Optimization of high-performance networks (2 + 2 PhD students)
  - Modeling techniques for heterogeneous systems (6 + 4 PhD students)

Recruiting now!

Questions

① What is heterogeneity?

Heterogeneity at the system level



Physical world

Mechanics, aerodynamics

Electronics

Control systems

Software platforms

Hardware platforms

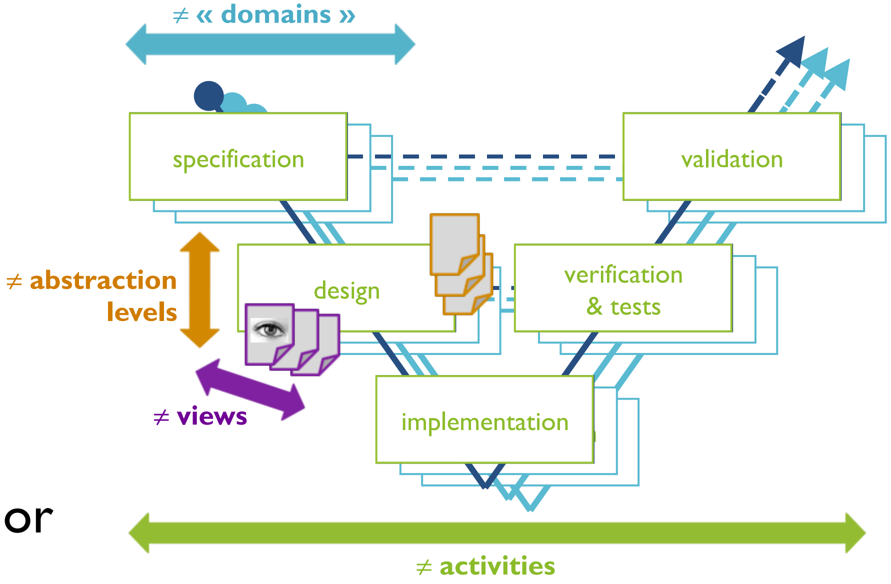
Energy

Networks

Sensors/ actuators

Heterogeneity at the model level

- Combination of components of different natures (signal processing, electronics, control...)
  - Composition of models



- Several abstraction levels
  - Refinement of models
- Orthogonal points of view
  - Models of functional and extra-functional properties/behavior
- Different activities and goals during a project
  - Models for different kind of analysis

Heterogeneity in ModHel'X

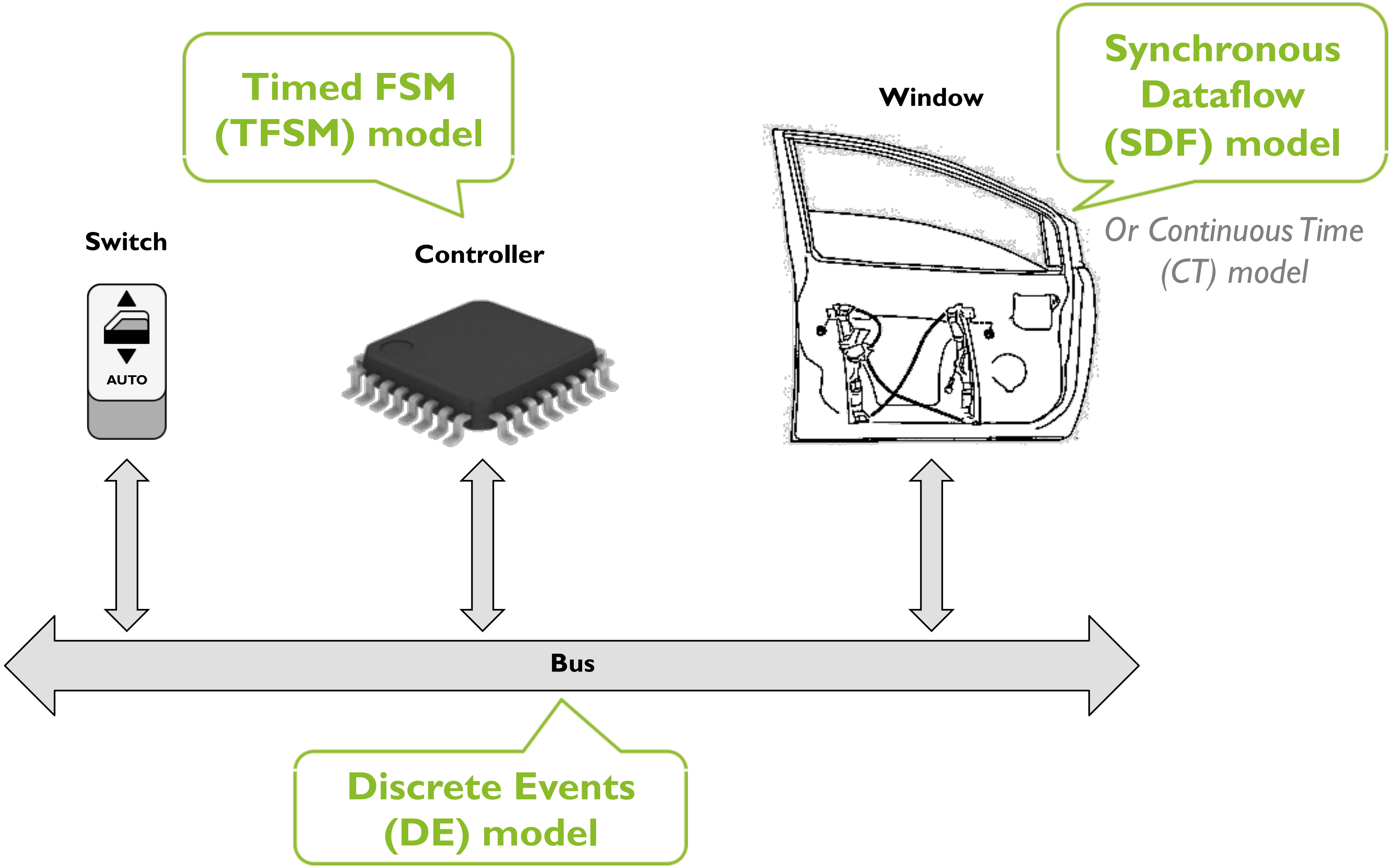
- Focus on the heterogeneity of the components of a system:
  - Heterogeneous components ➡ heterogeneous design paradigms
  - Interaction among components + environment ➡ model composition

- The problem we try to address =

How to compose models that are written using different modeling languages in order to be able to reason globally on a system under design?

- Experimental platform = ModHel'X

The power window example



Timed FSM (TFSM) model

Switch

AUTO

Controller

Window

Synchronous Dataflow (SDF) model

Or Continuous Time (CT) model

Bus

Discrete Events (DE) model

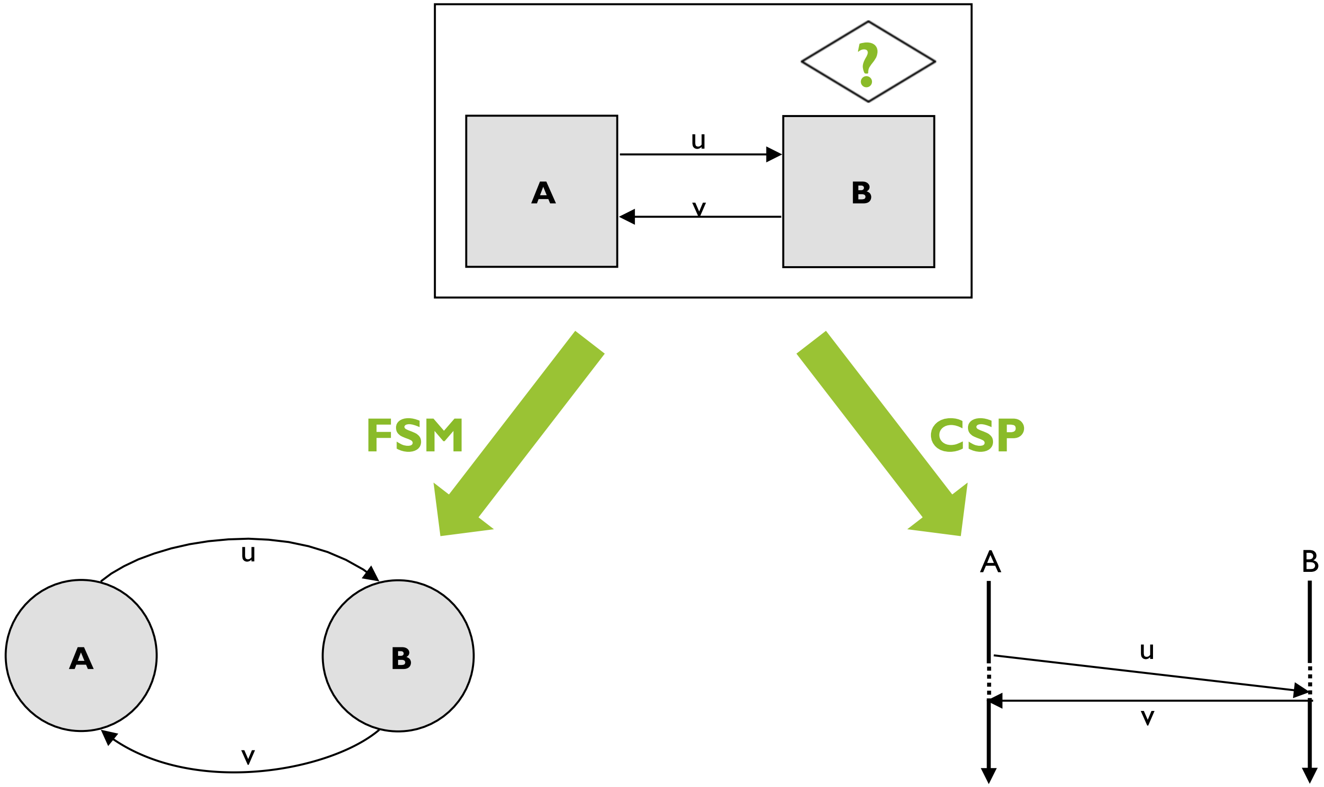
Questions

① What is heterogeneity?

② How to represent a modeling paradigm in a form that is “composable”?

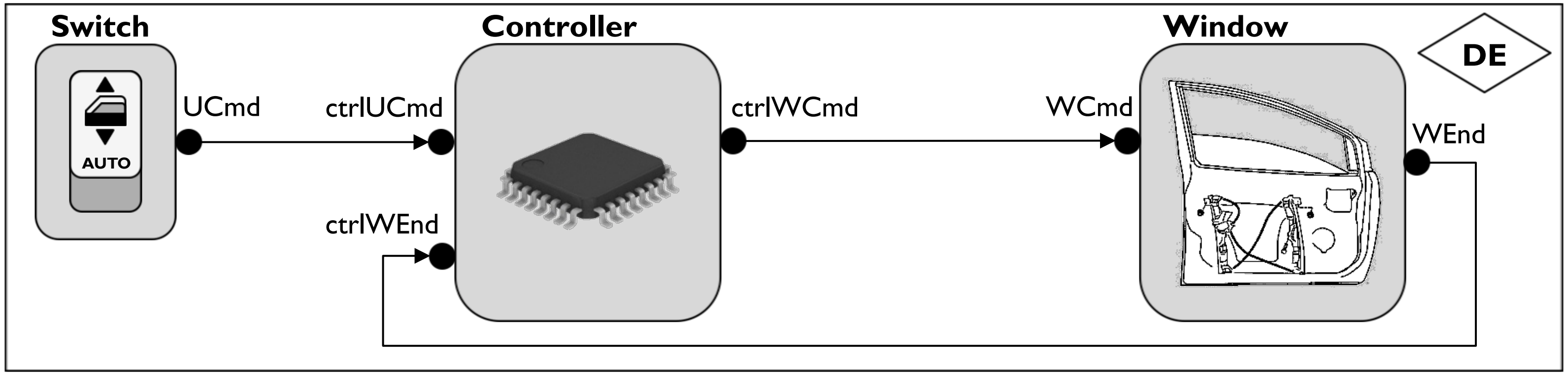
Model of Computation

- Represents the semantics of a modeling language
- Provides the rules for interpreting a model



Model = structure + MoC

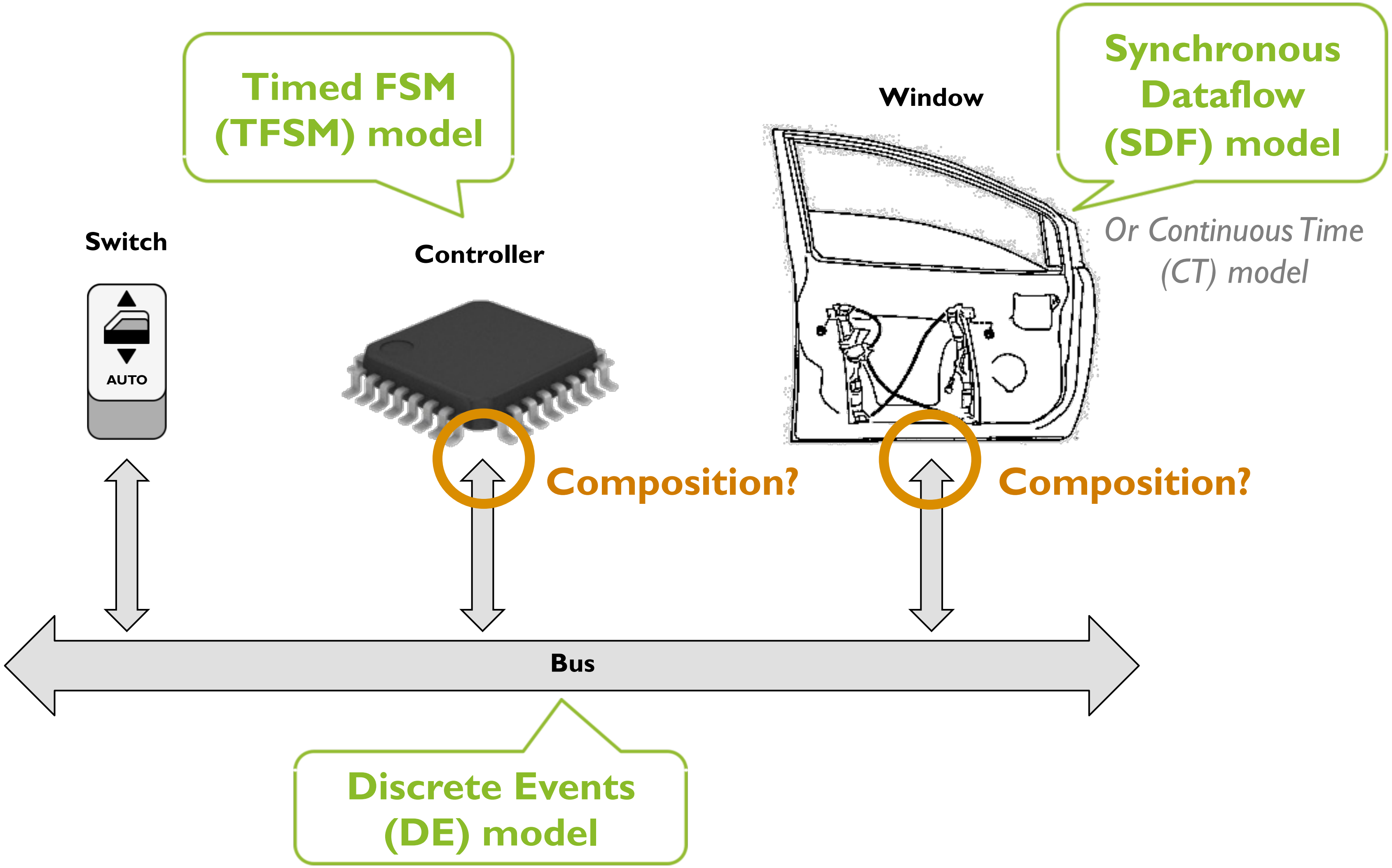
- The structure of a model is a set of interconnected blocks (black boxes)
- A MoC is used to provide an interpretation (semantics) of that structure



MoCs currently available in ModHel'X

- Discrete Events (DE)
  - Exchange of events 〈value, date〉
  - ≈ Network messages
- Synchronous Data Flow (SDF)
  - Flows of sampled data
  - Multi sample rate
  - ≈ Simulink block diagrams
- Timed Finite State Machines (TFSM) [+ FSM + *Charts]
  - Timed transitions: "after(T)"
  - ≈ very simplified UML's Stateflow
- Petrinets

The power window example (again)



Timed FSM (TFSM) model

Synchronous Dataflow (SDF) model

Or Continuous Time (CT) model

Composition?

Composition?

Discrete Events (DE) model

Questions

① What is heterogeneity?

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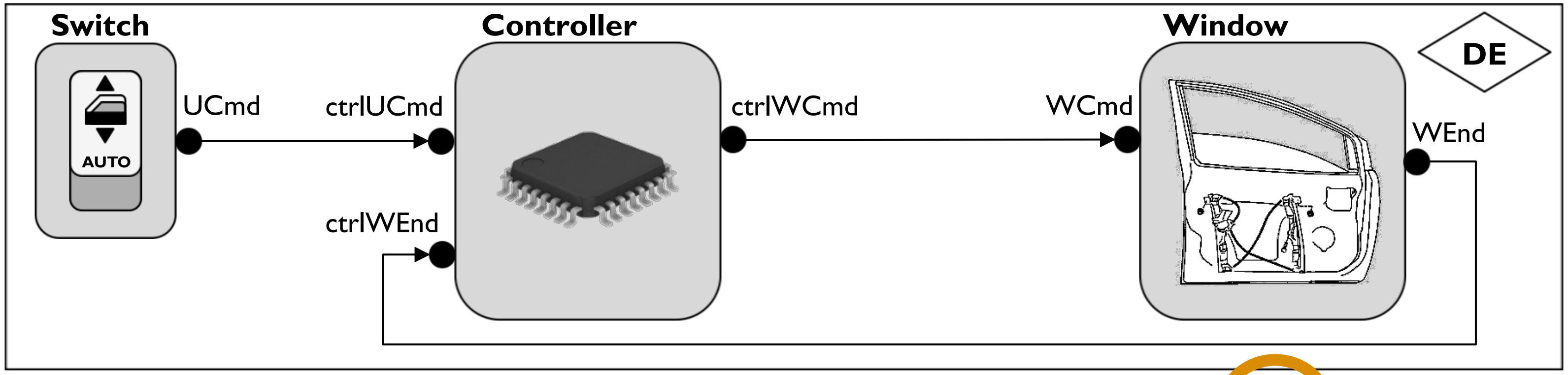
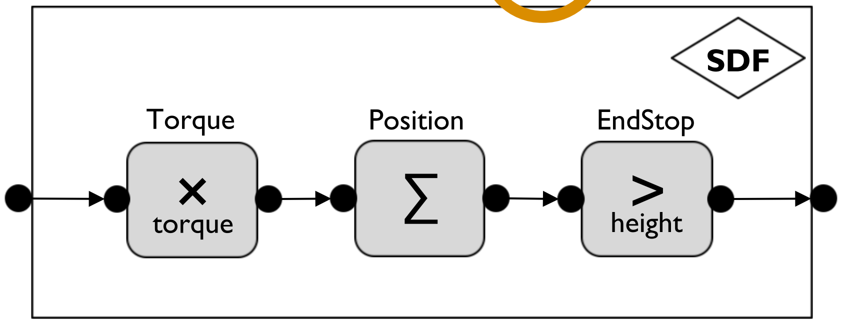
③ How to compose models that use different modeling paradigms?

Composition of heterogeneous models



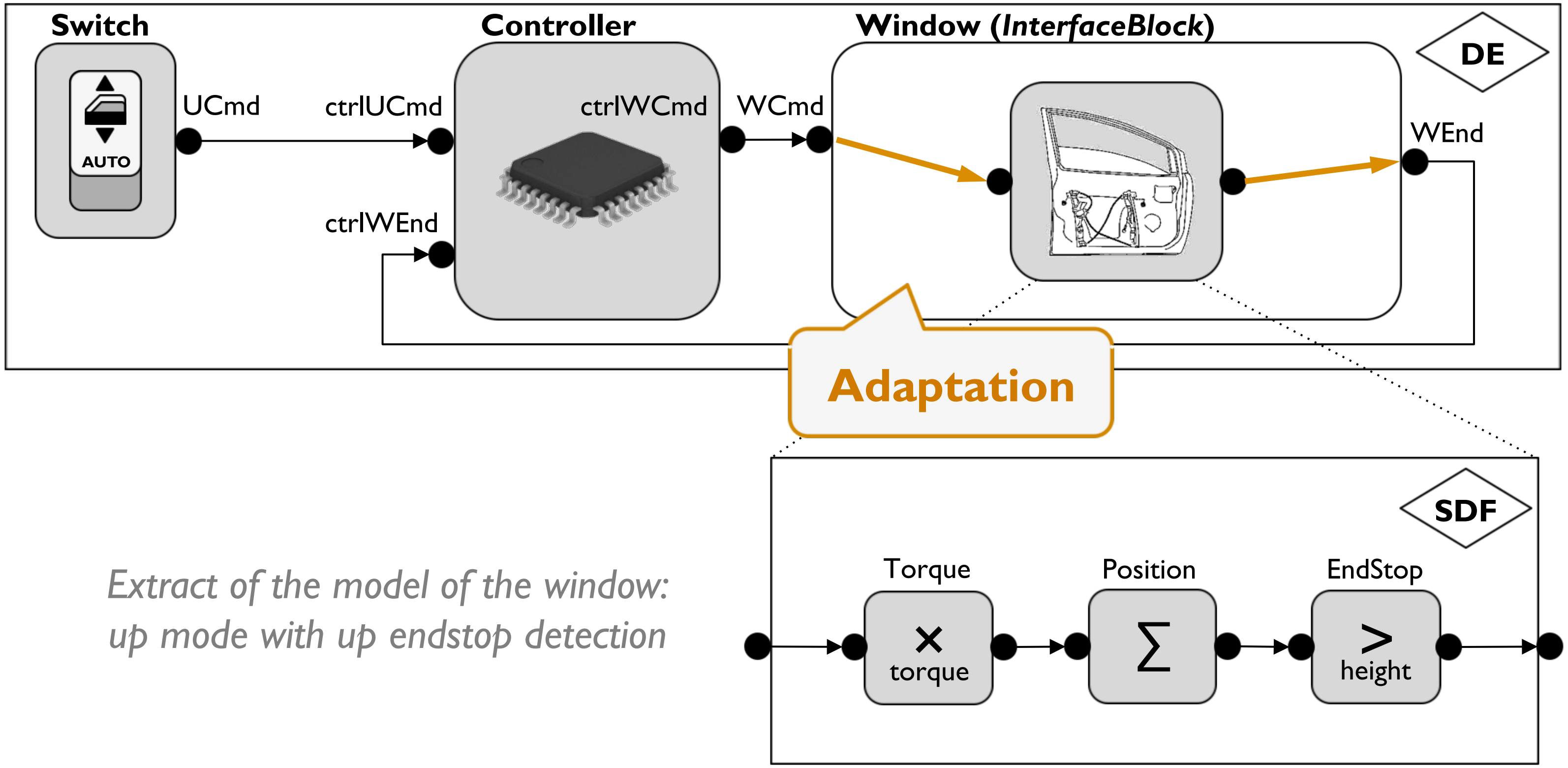
Composition?

Extract of the model of the window: up mode with up endstop detection



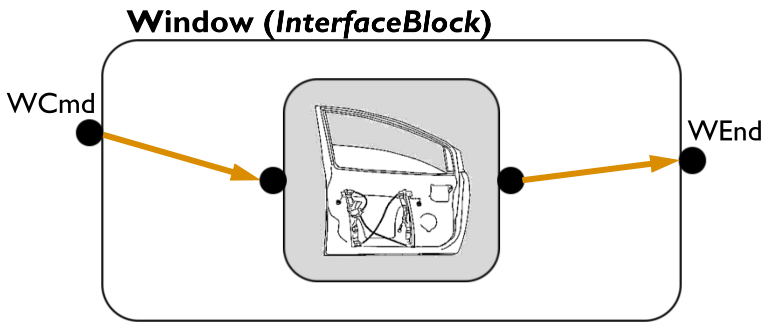
Composition of heterogeneous models

- "Interface blocks" are used to embed a model into a block
  ➡ Support for heterogeneity through hierarchy

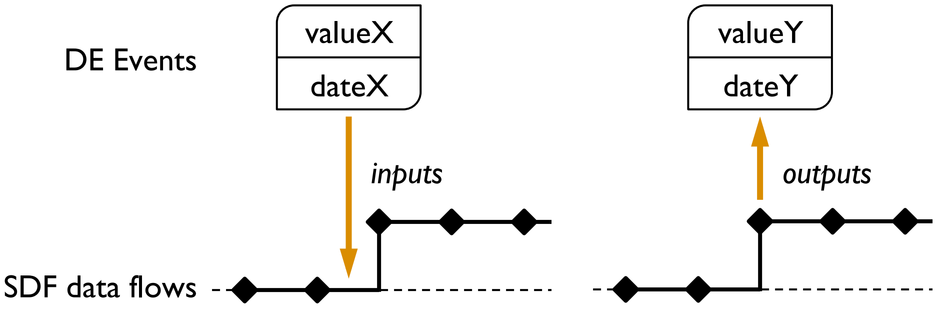


Extract of the model of the window:
up mode with up endstop detection

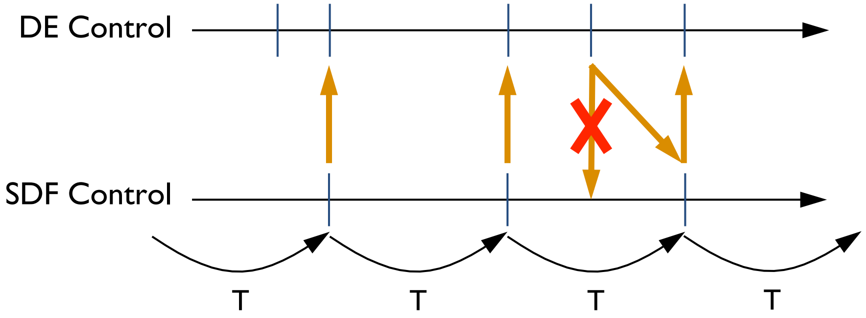
What is adaptation?



- Adaptation of data
  - Forms
  - Values



- Adaptation of control flow
  - “Moments” at which “things” happen



- Adaptation of time notions
  - Time scales
  - Time forms (seconds, revolutions, centimeters…)

Outline

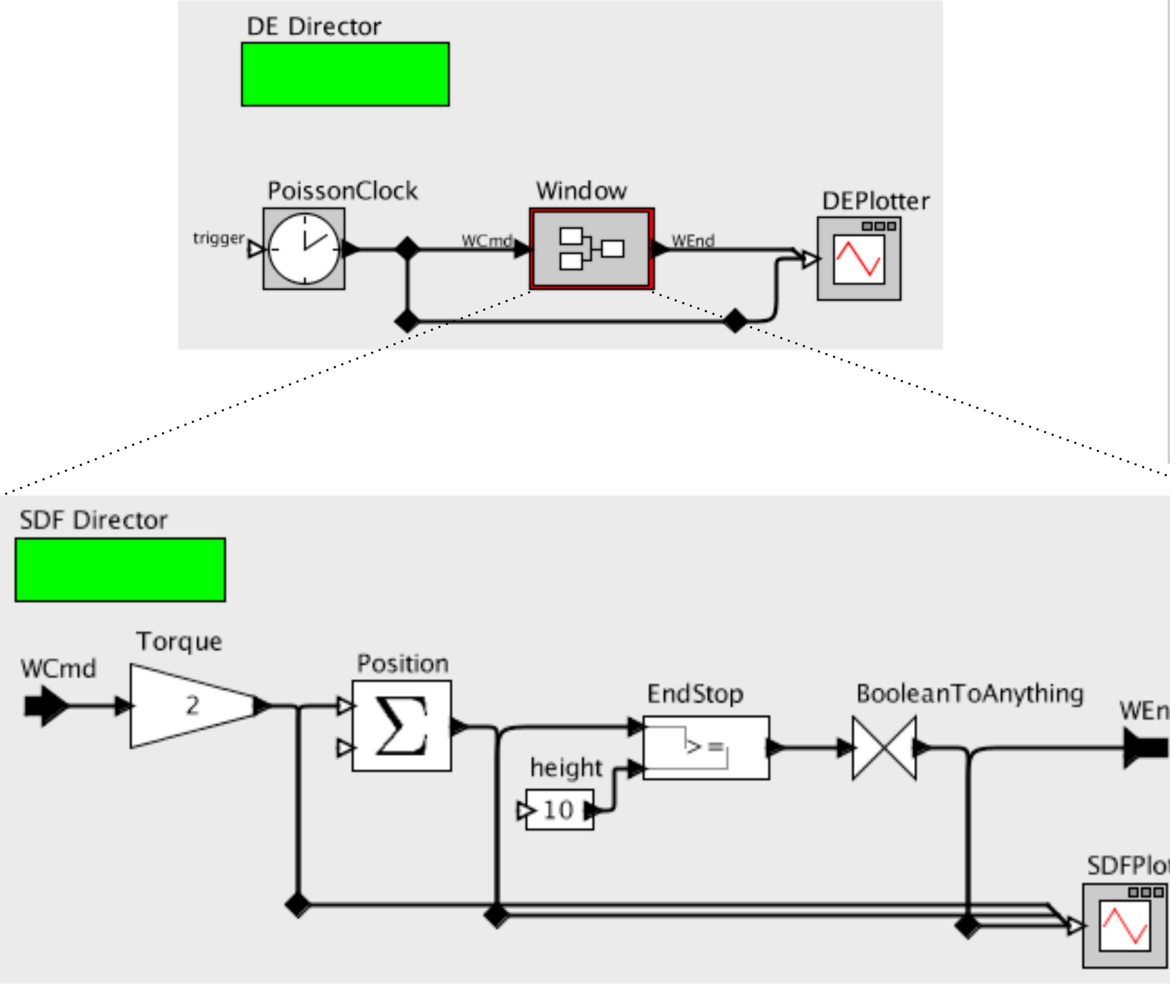
① What is heterogeneity?

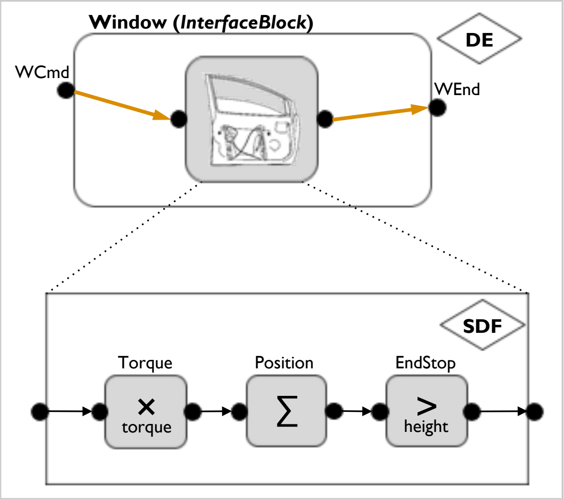
② How to represent a modeling paradigm in a form that is "composable"?

③ How to compose models that use different modeling paradigms?

④ What is the benefit of modeling the adaptation explicitly and apart from the models?

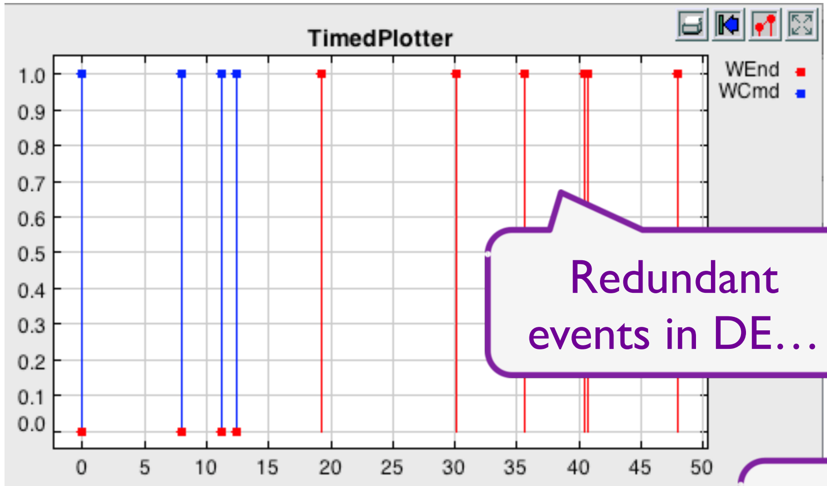
The window model in PtolemyII





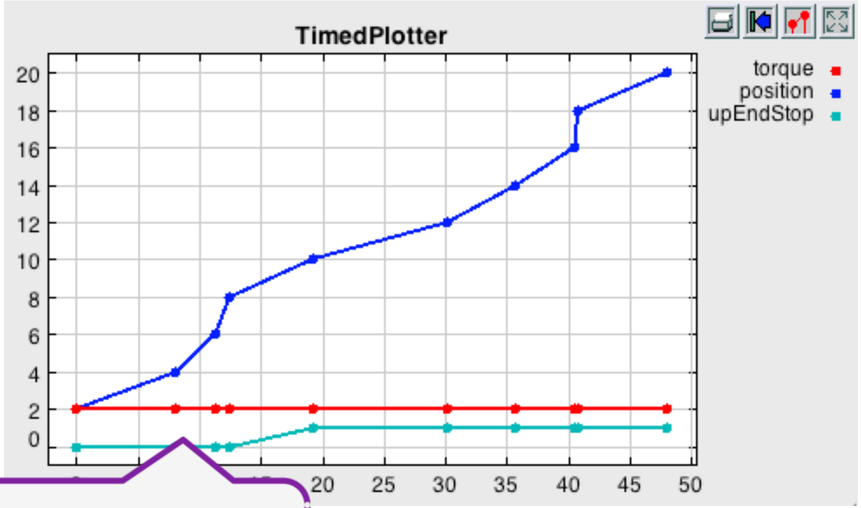
Model of the window in "open loop": up mode with up endstop detection

The window model in PtolemyII



Redundant events in DE…

Events in DE



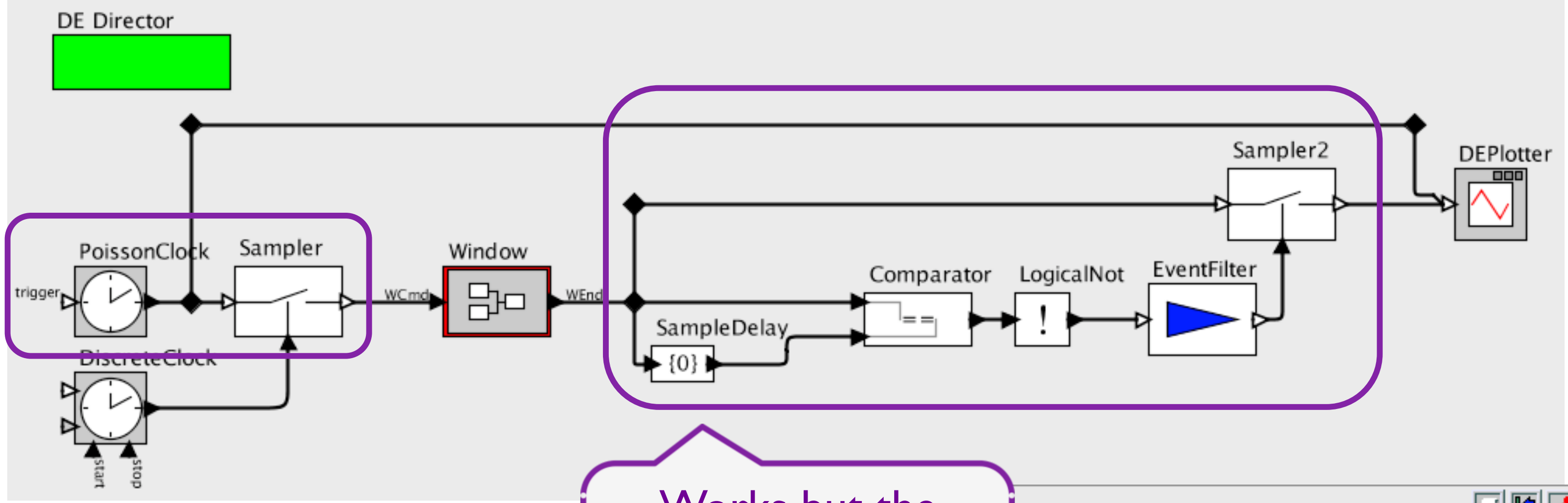
SDF model not regularly sampled…

Flows in SDF

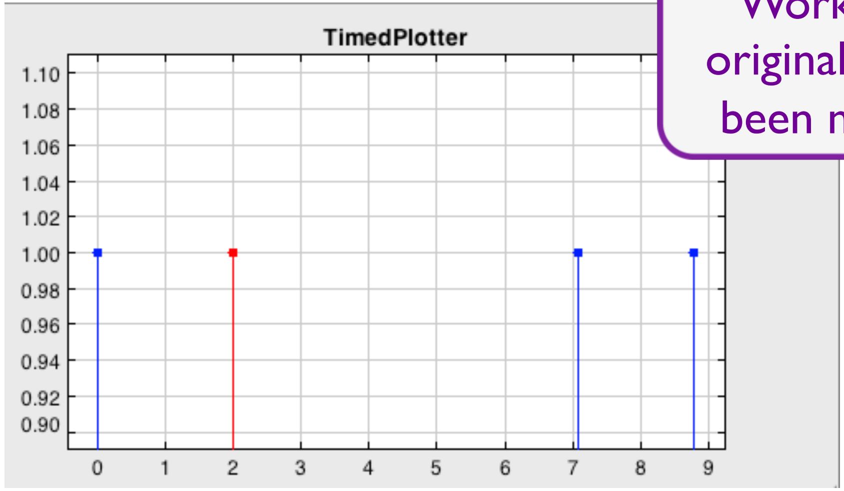
- Default adaptation:
  - The SDF model reacts only when events are processed in DE
  - DE events are produced in the DE model each time the SDF model reacts

- Changing the adaptation means modifying one of the two models

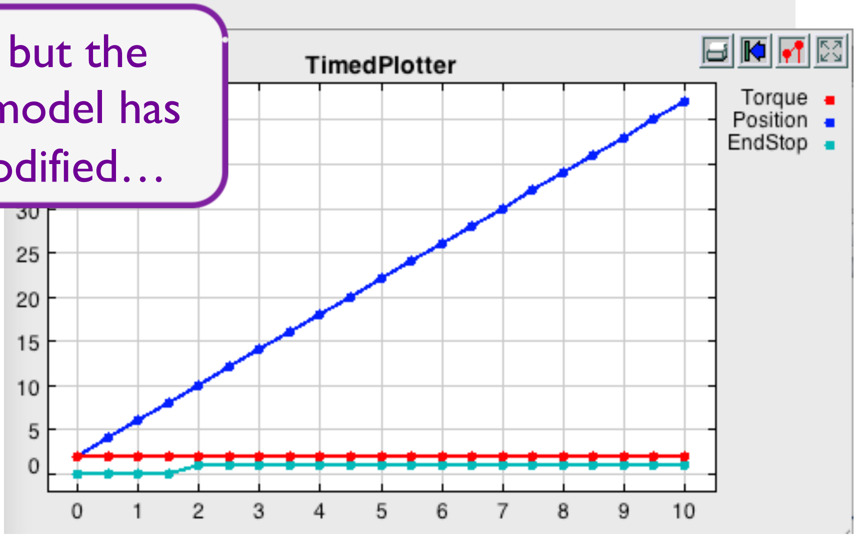
Adapted model in PtolemyII



Works but the original model has been modified…



Events in DE



Flows in SDF

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Key points

- Our approach:
  - Models of Computation (MoCs) for representing the semantics of design paradigms
  - Semantic adaptation for composing heterogeneous models using hierarchy

- Goals of ModHel'X:
  - Extensible set of MoCs
  - Explicit, customizable and modular semantic adaptation between hierarchical models

Current research directions

- Modeling MoCs
  - Imperative form ➡ execution
  - Declarative form ➡ verification & validation
  - Variants of a MoC? Reusability of (parts of) a model of a MoC?
- Modeling Semantic Adaptation
  - Clock calculus to describe adaptation of time and control (extension of CCSL)
  - Language to describe adaptation of data
  - Patterns of adaptation
- Multi-view modeling
- Beyond heterogeneous model simulation: test, code generation, model checking…

MERCI!
THANK YOU!
FRAPAR.