

# Heterogeneous Modeling of Embedded Software

Workshop on New Visions  
for Software Design and  
Productivity

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# Aspects of embedded software

- Interaction with physical processes
  - sensors, actuators, processes
- Critical properties are not all functional
  - real-time, fault recovery, power, security, robustness
- Heterogeneous
  - hardware/software, mixed architectures
- Concurrent
  - interaction with multiple processes
- Reactive
  - operating at the speed of the environment

These features look more like hardware!



# Heterogeneous models of computation

Discrete-Event

Finite State Machine

Continuous-Time

Model of computation is the "laws of physics" of component interaction

# Example: Controlling an inverted pendulum

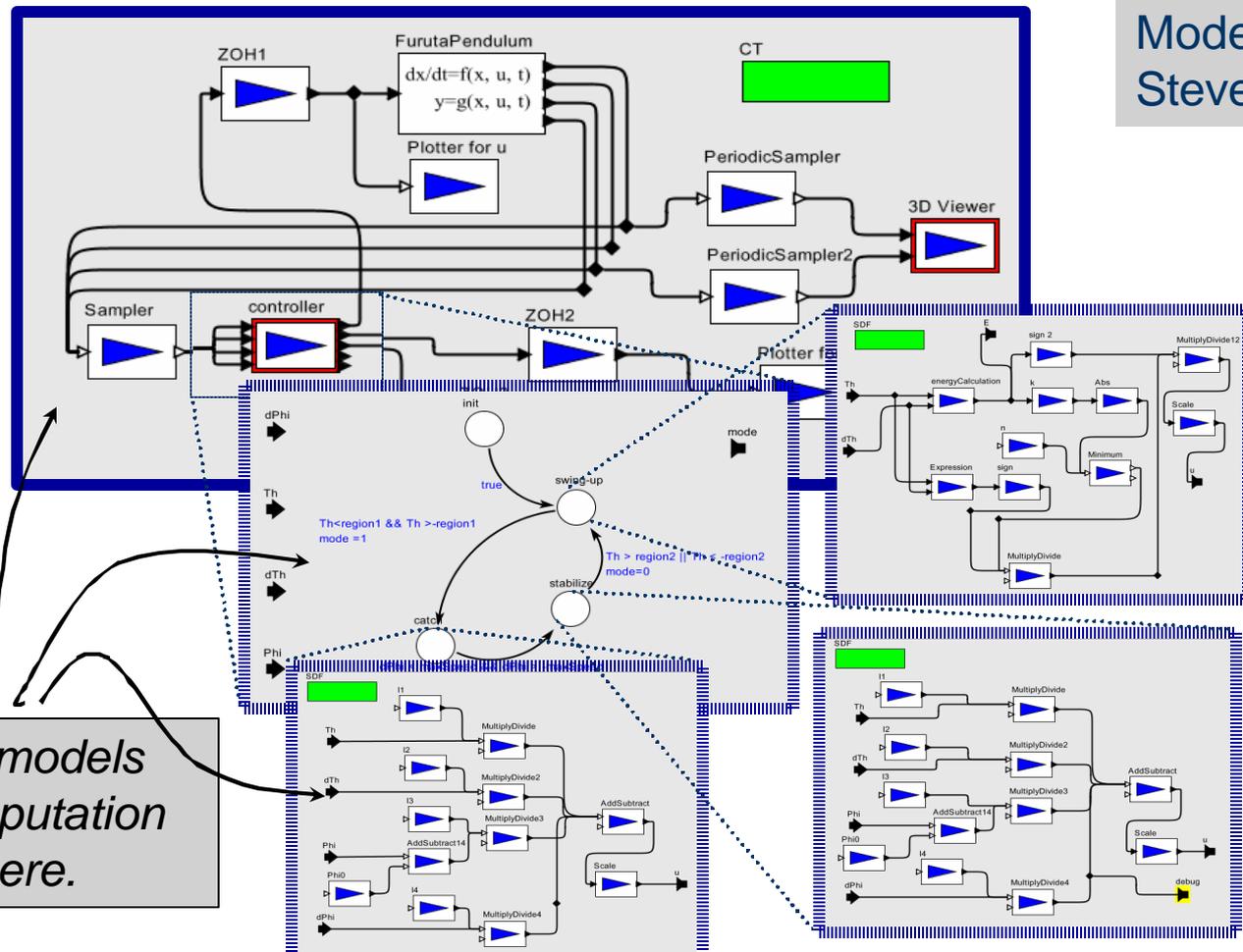


The Furuta pendulum has a motor controlling the angle of an arm, from which a free-swinging pendulum hangs. The objective is to swing the pendulum up and then balance it.

*Representative of many embedded systems*

# Hierarchical Heterogeneity

Models by Jie Liu and Steve Neuendorffer

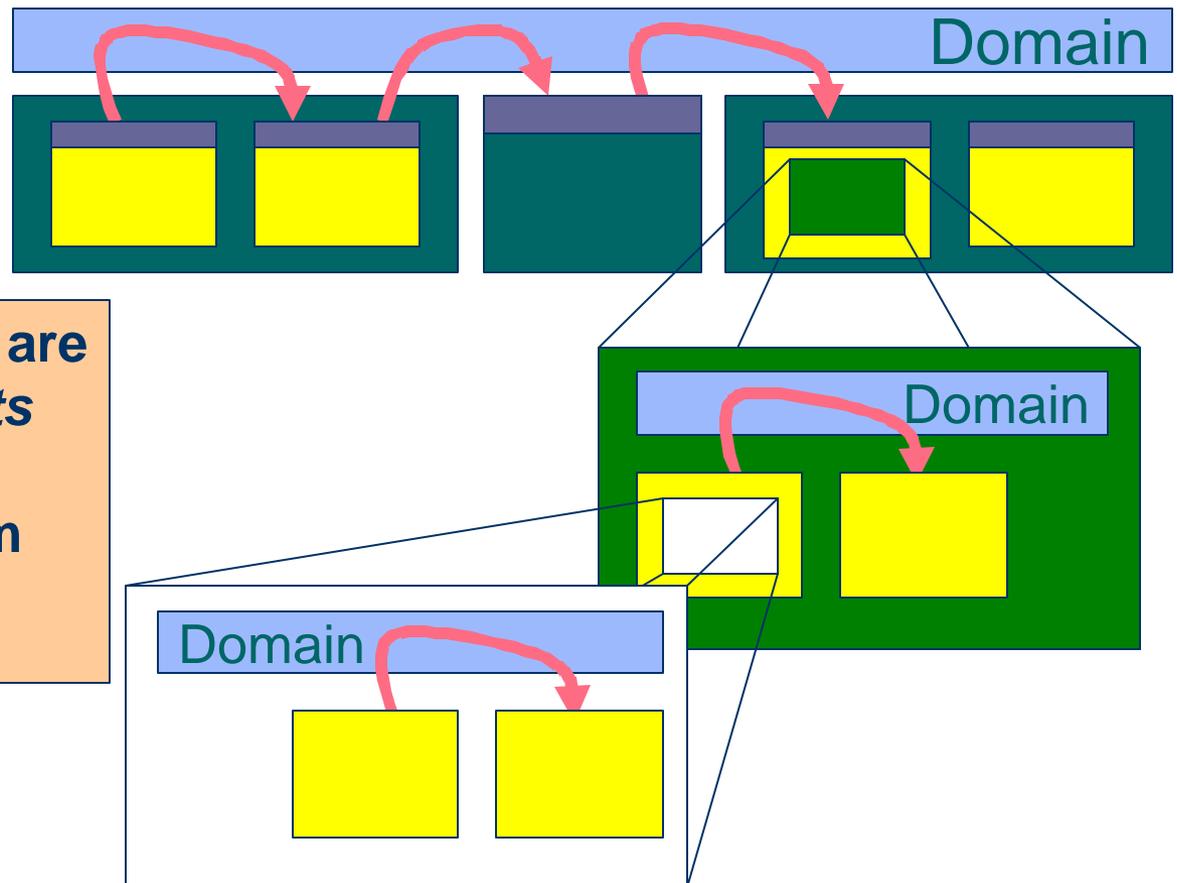


*Components are actors with ports*

*Model of computation controls interaction*

*Three models of computation used here.*

# Therefore: Hierarchical, Compositional Models are Key



*Actors with ports are better than objects with methods for embedded system design.*

# A Laboratory for Exploring Component Frameworks



## Ptolemy II -

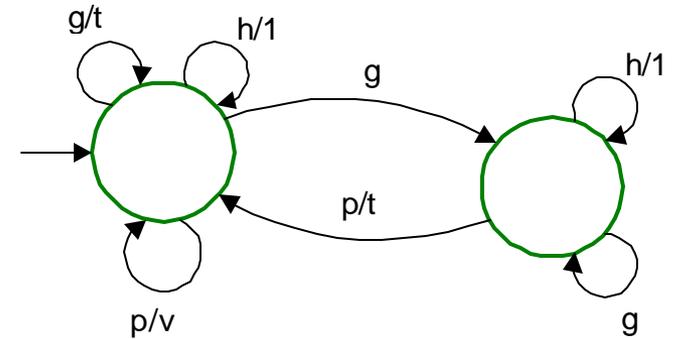
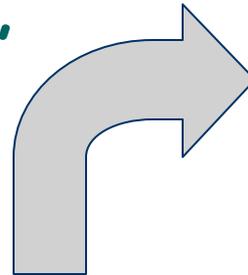
- Java based, network integrated
- Several frameworks implemented

- A realization of a model of computation is called a "domain." Multiple domains can be mixed hierarchically in the same model.

<http://ptolemy.eecs.berkeley.edu>

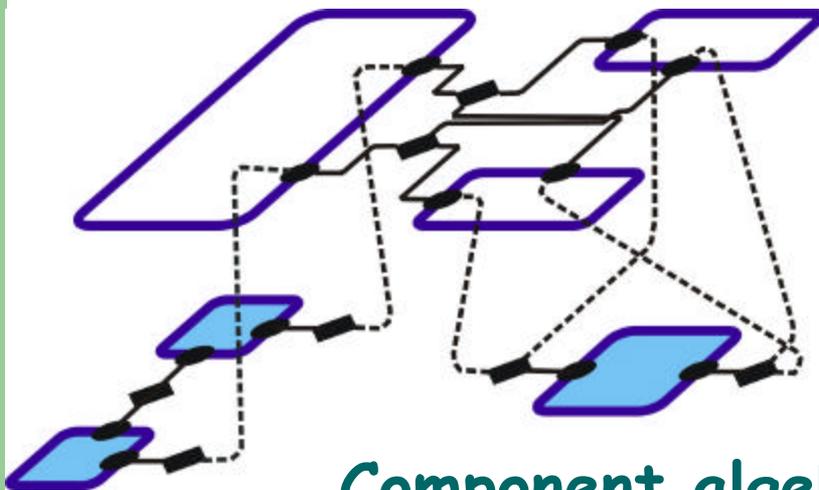
# Interface Theories (de Alfaro and Henzinger)

"Implements"



Interface algebra

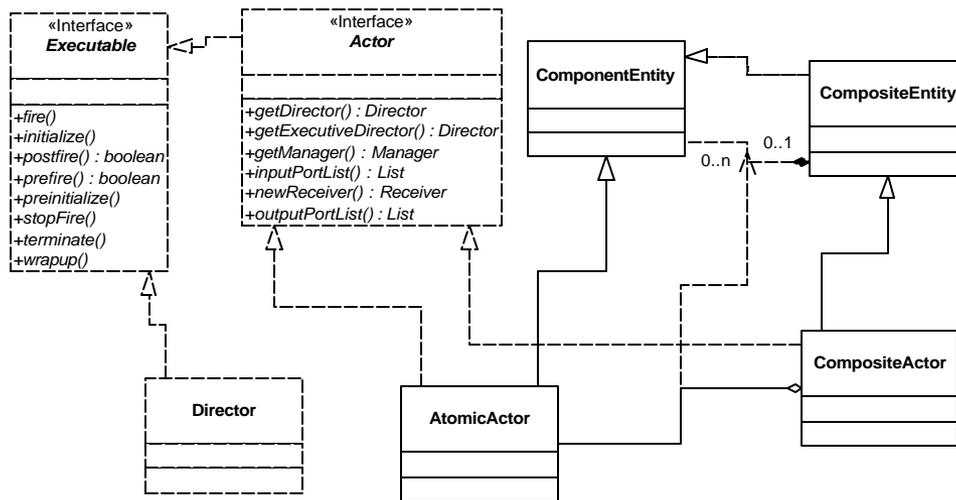
- Functional requirements
- Timing constraints
- Liveness and concurrency
- Refinement



Component algebra

# Implementation Architecture - API

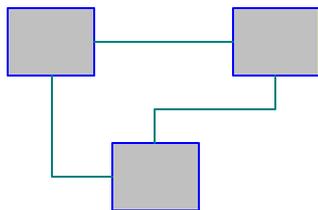
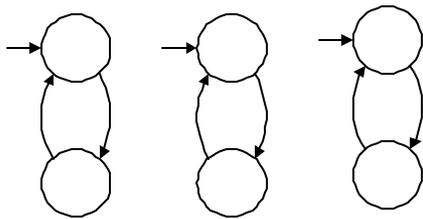
- Programmer's API exposes component model and an execution model
  - Conventional, well-understood
  - Difficult to extend, single-language



Ptolemy

# Implementation Architecture - Compile to Abstract Machine

- Separates programmer's model from implementation model
  - Extensible, retargetable, optimizable
  - Supports "real" embedded systems



*component*

*channel*

*event*

*time*

*action*

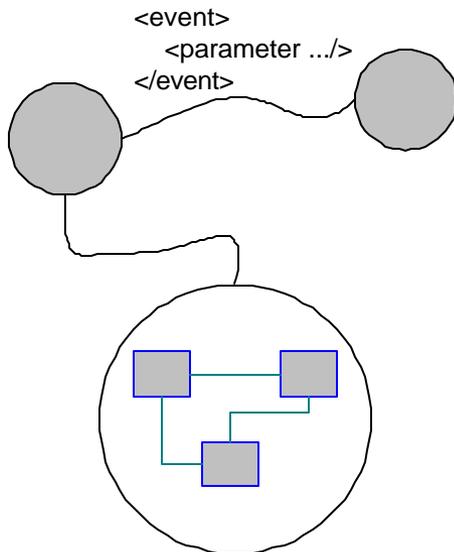
*transition*

... ? ...

**e-machine  
Calif**

# Implementation Architecture - Protocol

- Simple protocol exposes MoC "primitives"
  - Distributed, cross-language, legacy support
  - Clients, servers, peers



*tagged sequences*

*precise reaction*

... ? ...

**eg Nephest?**

# Conclusions

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- Software experts are unlikely to solve the embedded software problem on their own.
- Actors with ports are better than objects with methods for embedded system design.
- Well-founded models of computation matter a great deal.
- Further research can extend the application of hierarchical heterogeneous models of computation in embedded systems.