Modeling Heterogeneous Semantics in Ptolemy

with Modular Actor Interfaces

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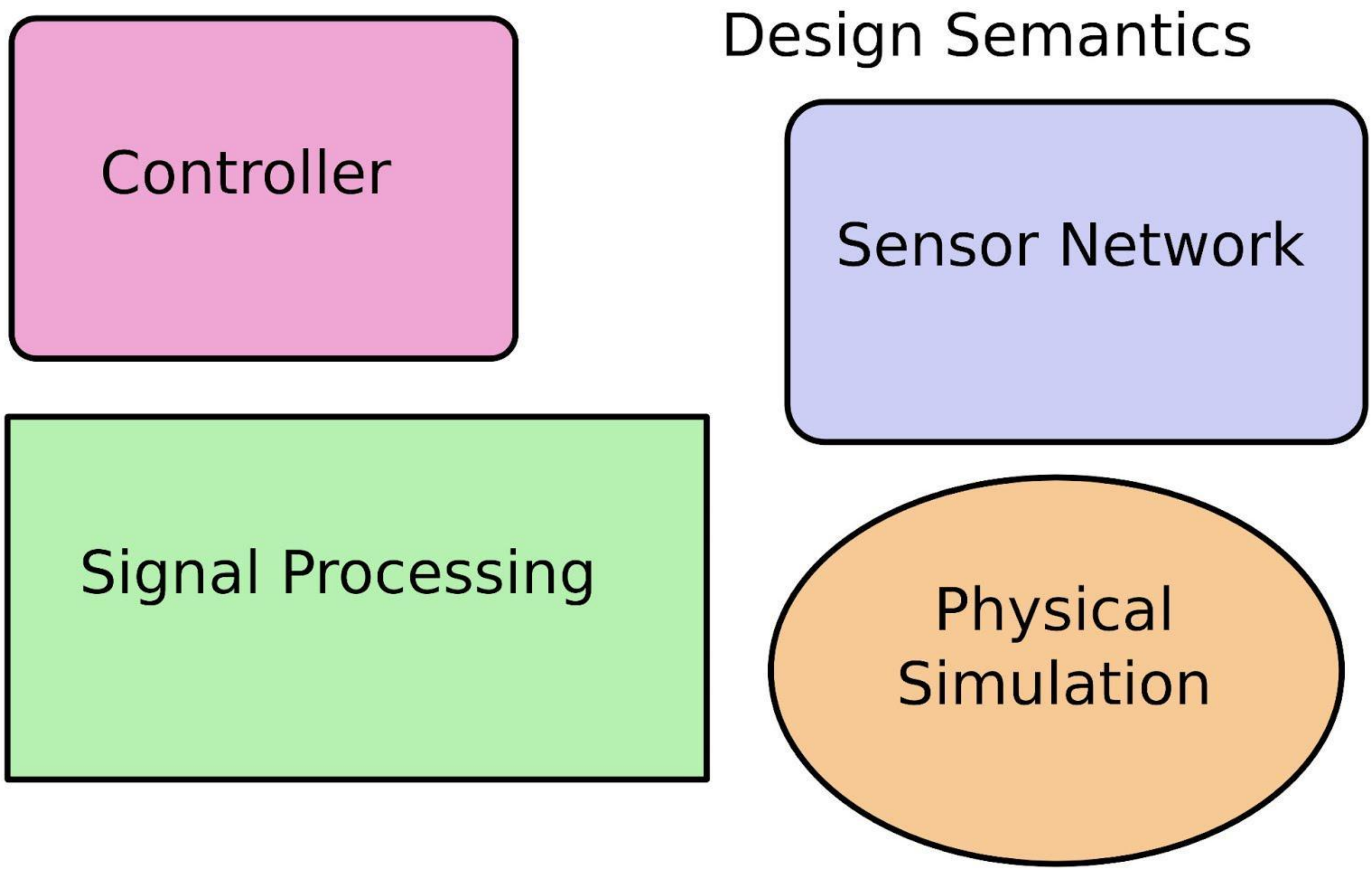
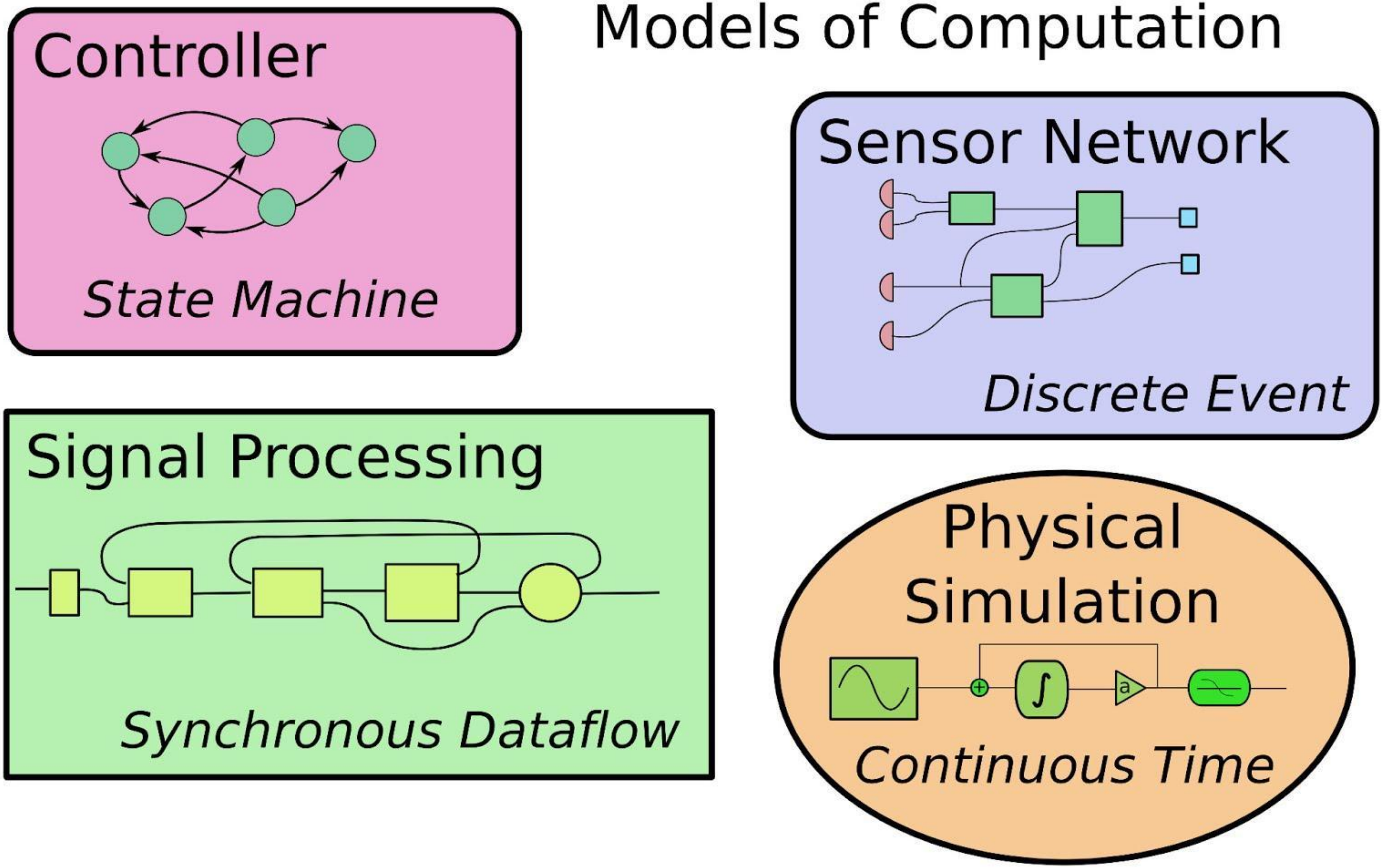
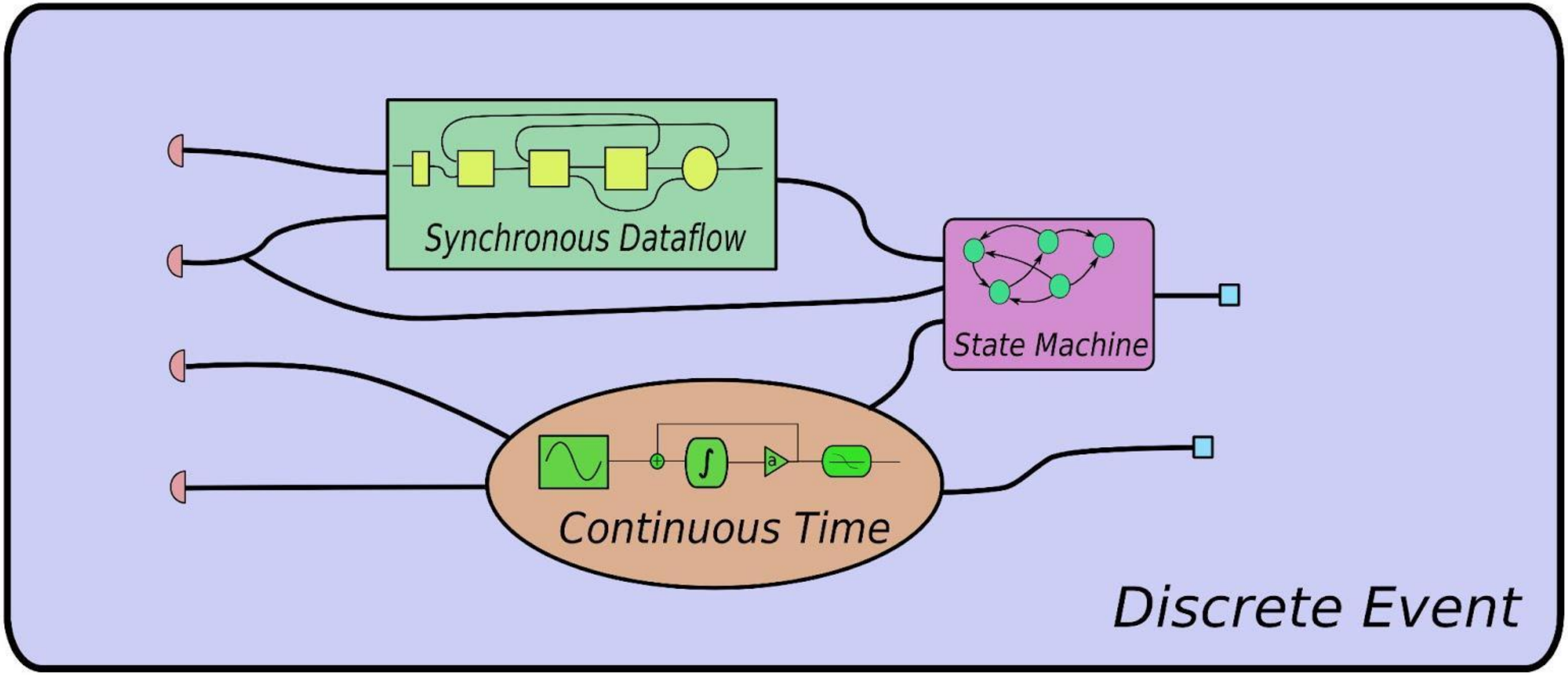
working with Professor Edward A. Lee


Design Semantics
Controller
Sensor Network
Signal Processing
Physical
Simulation

Models of Computation

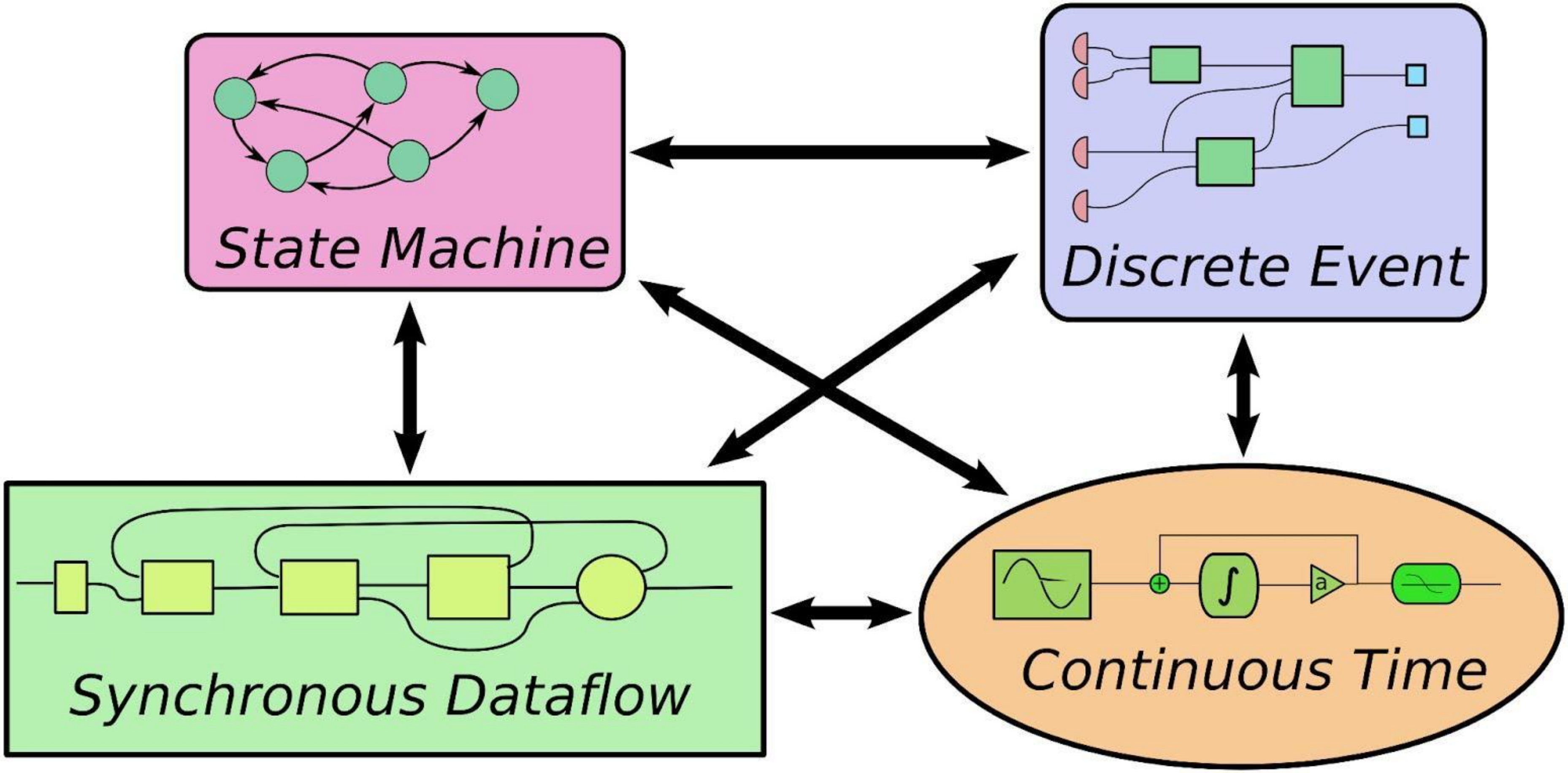


Heterogeneous Systems



Different parts of a system and different levels of hierarchy can have different Models of Computation

Interoperability



Reasoning About Heterogeneity

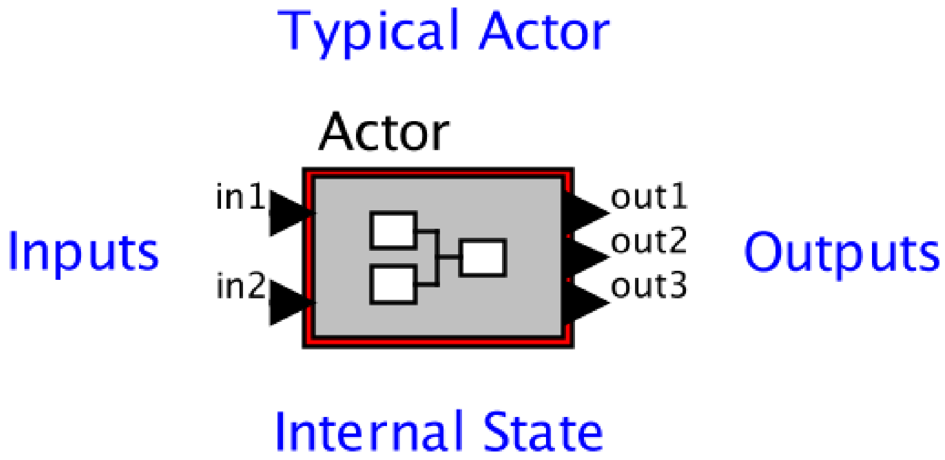
- There needs to be a way to reason about the composition of models with different Models of Computation.

- This is necessary for establishing a consistent semantics for heterogeneous systems.
- This can be used to do analyses and forms of verification that cross the boundaries of heterogeneous composition.

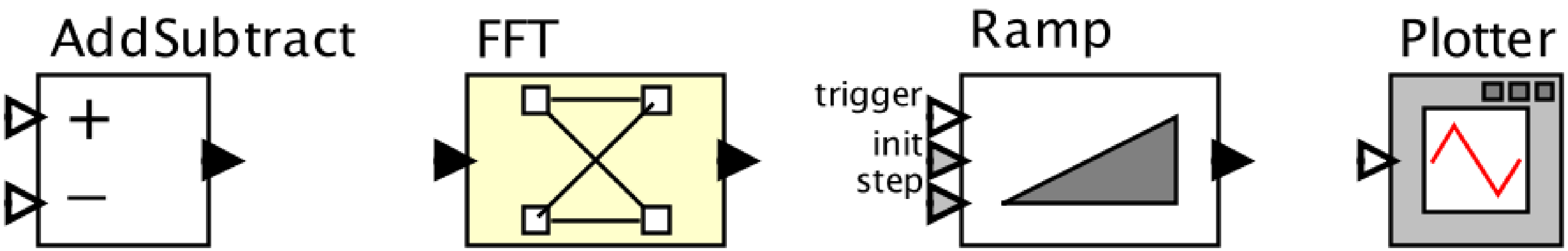
Ptolemy II

- An open source research platform for modeling systems.
- Implements an Actor Oriented language for model development.
- Allows hierarchical design and the heterogeneous composition of different Models of Computation.
- ~2.5 Million Lines of Code.
- Code generation.

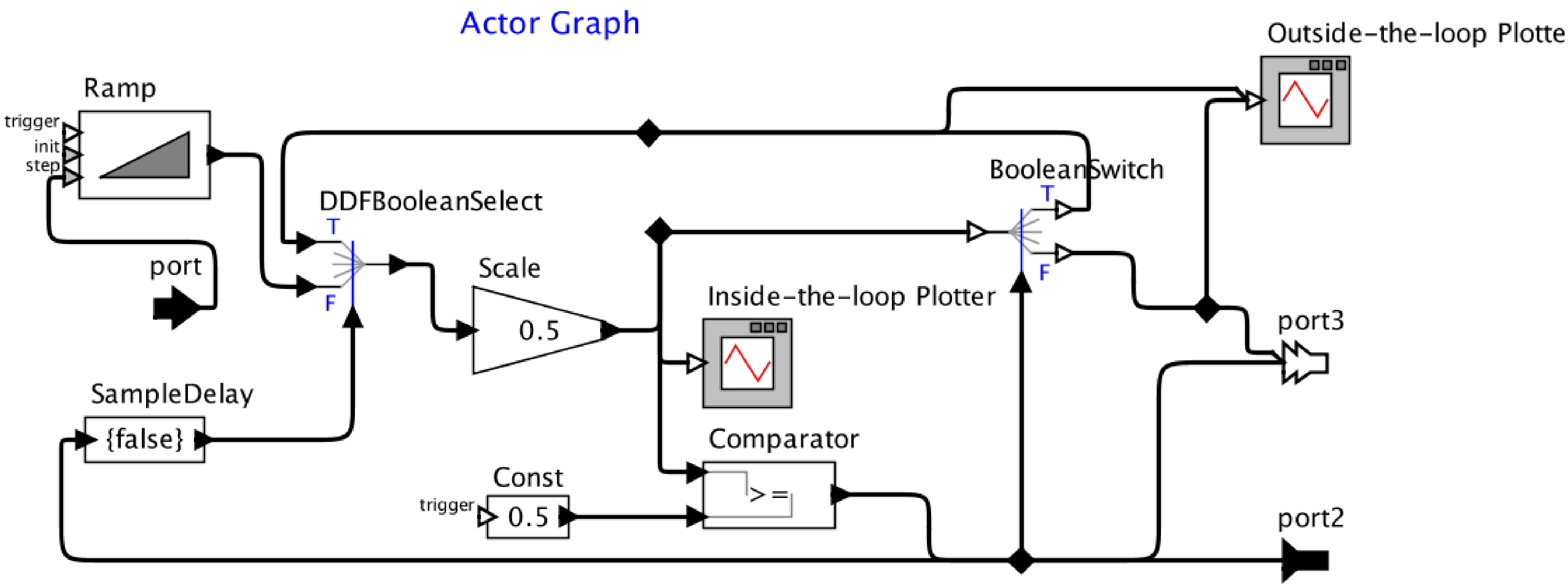
Actors



Some Specific Actors

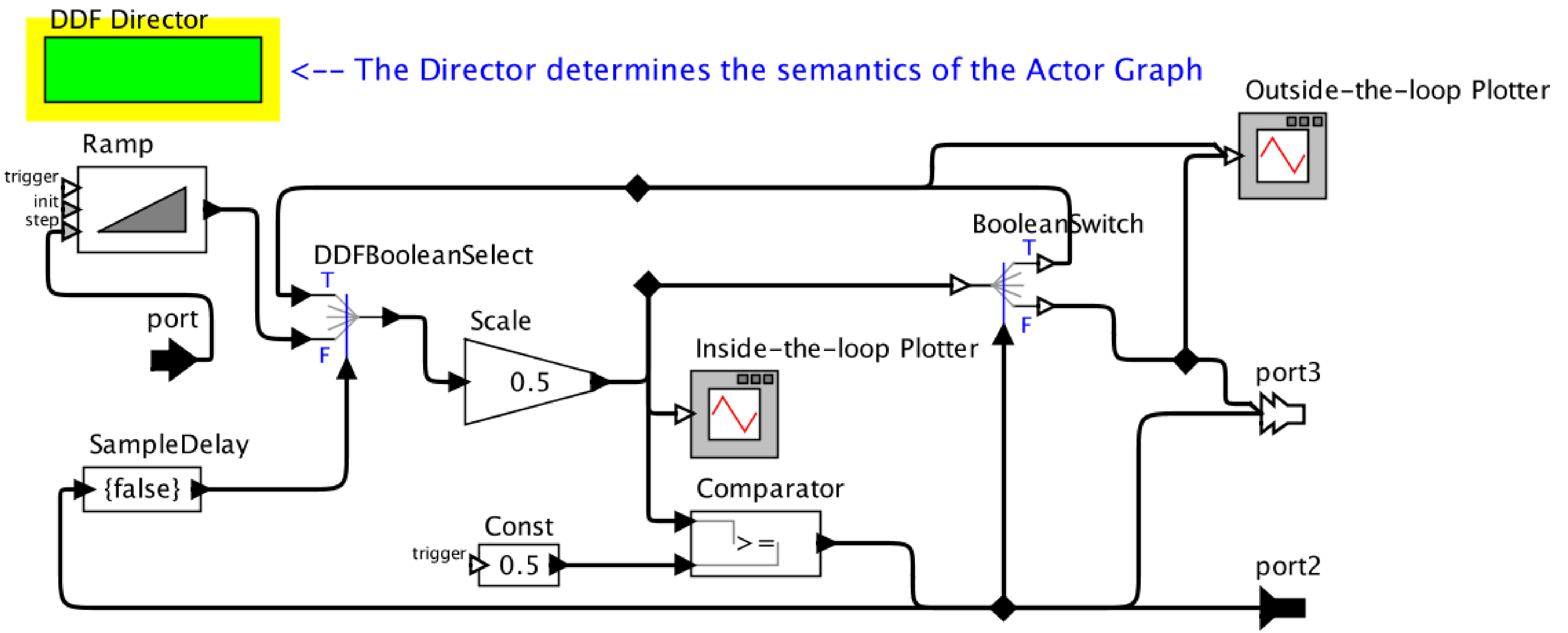


Actor Graphs



Author: Gang Zhou
(based on Ptolemy Classic demo)

Models



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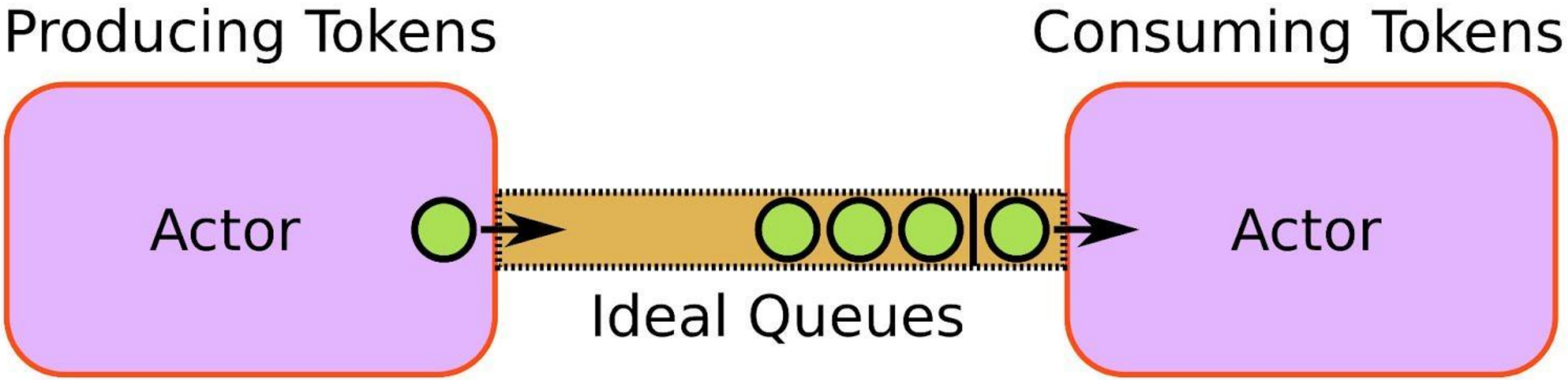
(based on Ptolemy Classic demo)

Dataflow Directors :

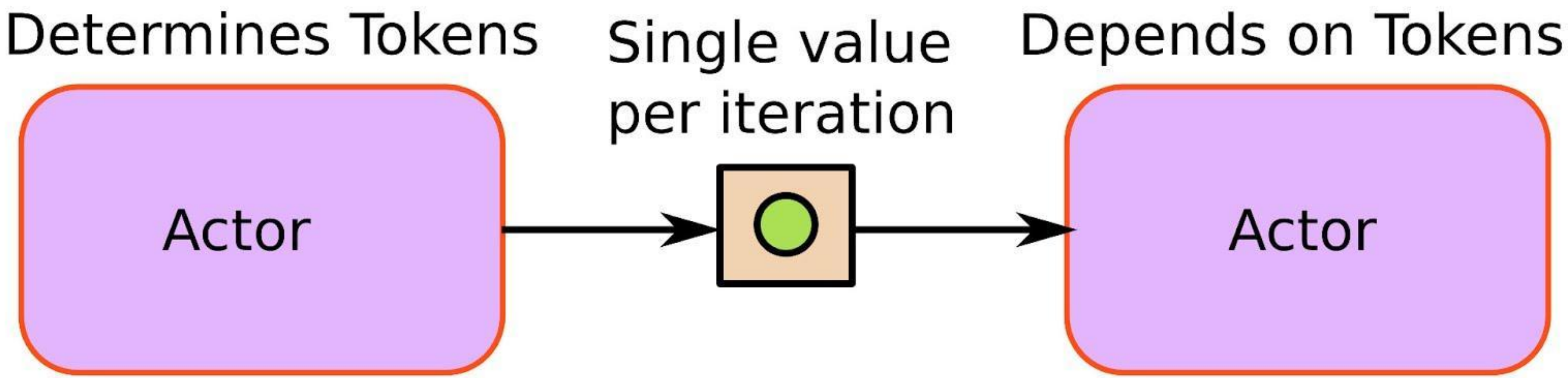
DDF, PSDF, CSDF, MDSDF, HDF, SDF, etc...



SDF : Production and Consumption rates are fixed. Scheduability is decidable, and if a model is scheduable, it can be scheduled periodically with fixed-sized buffers.

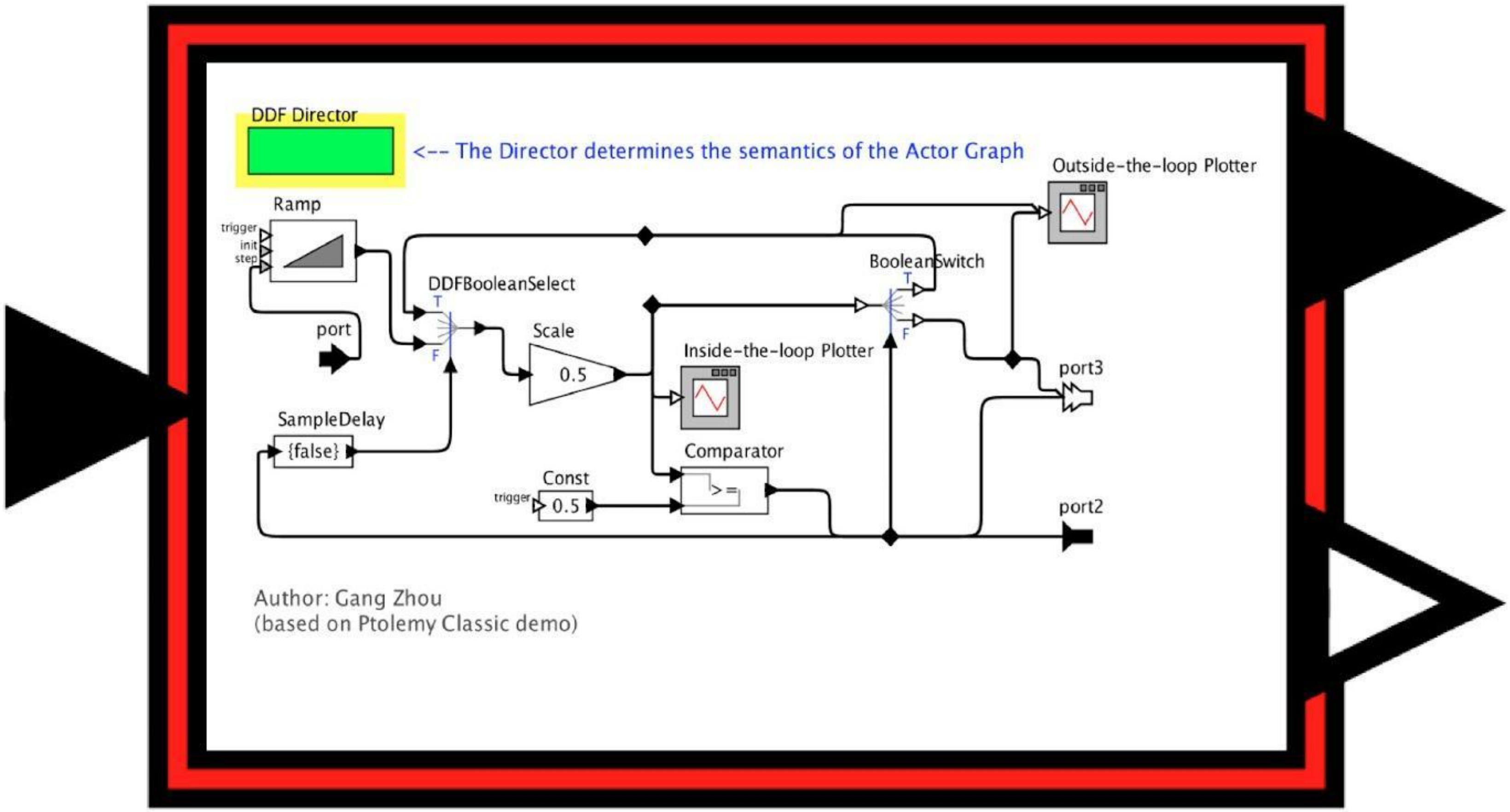
Synchronous Directors :

SR, DE, CT, etc...

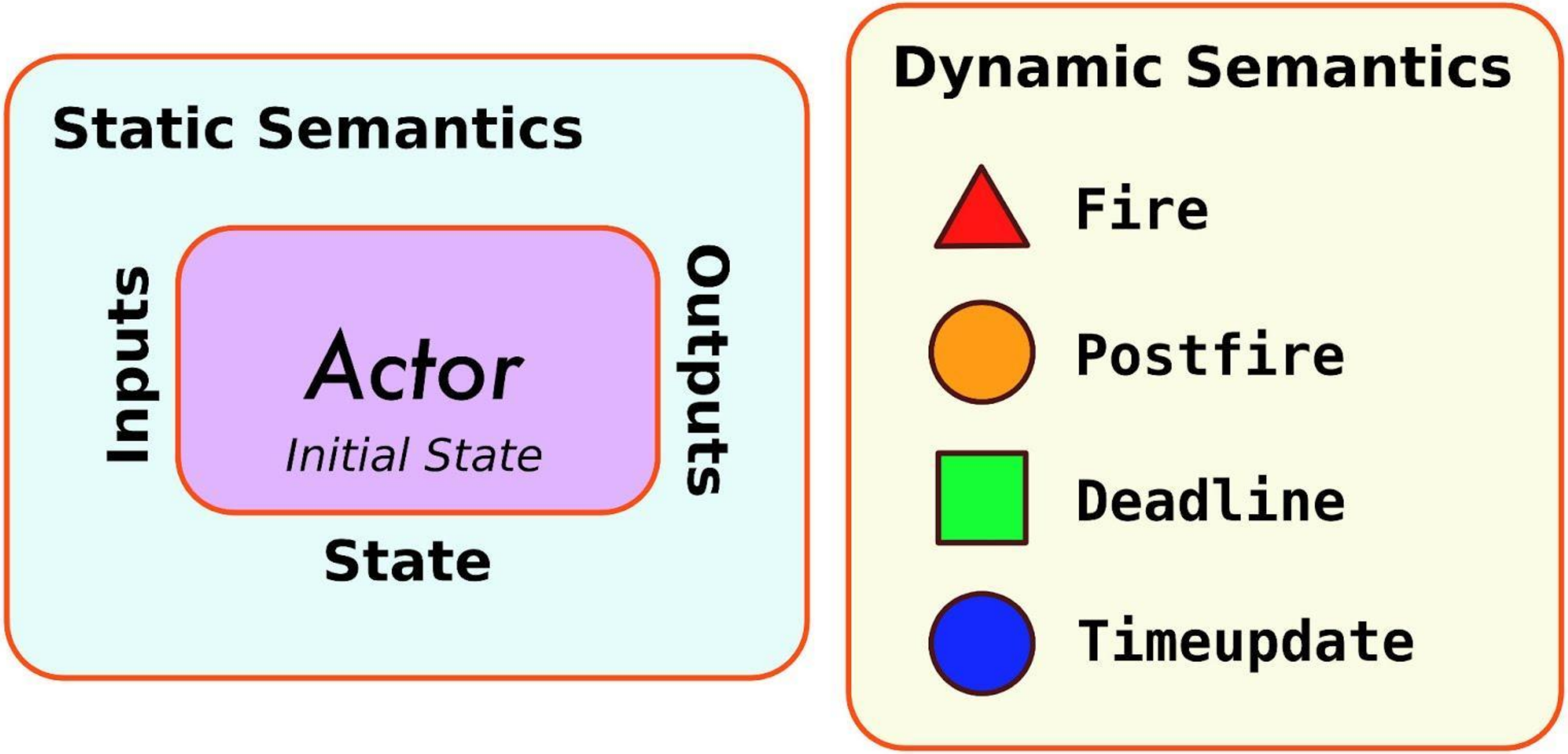


SR : If actors in a model are monotonic then there exists a unique solution for the value of every relation that can be reached through a fixed-point iteration.

Composite Actors

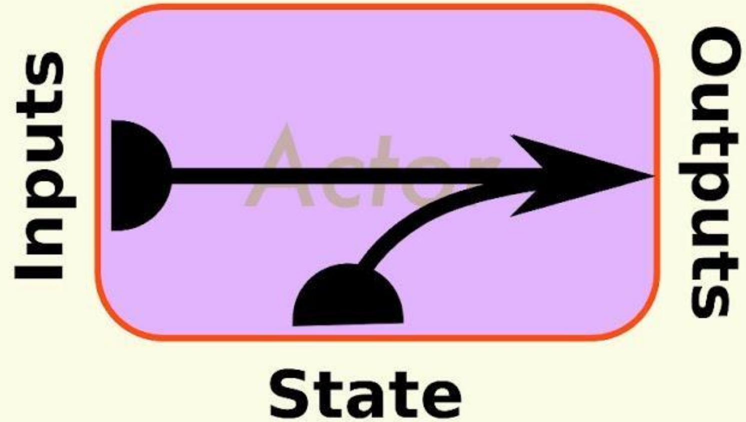


Modular Actor Interface

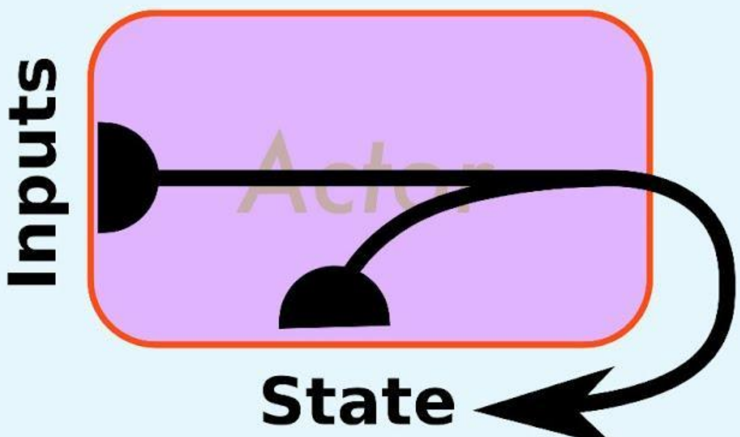


Fire

Produces outputs
from inputs and state



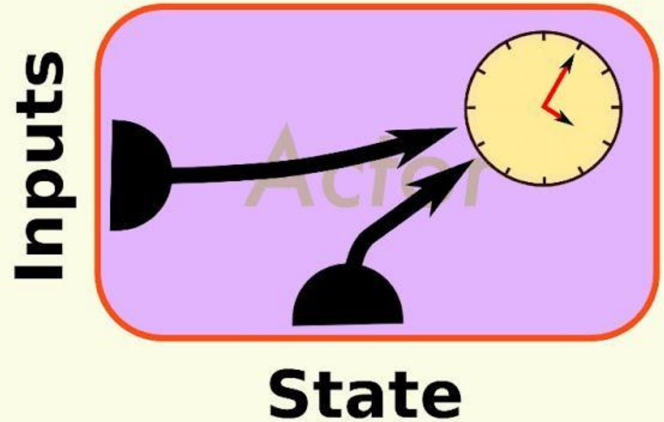
Postfire

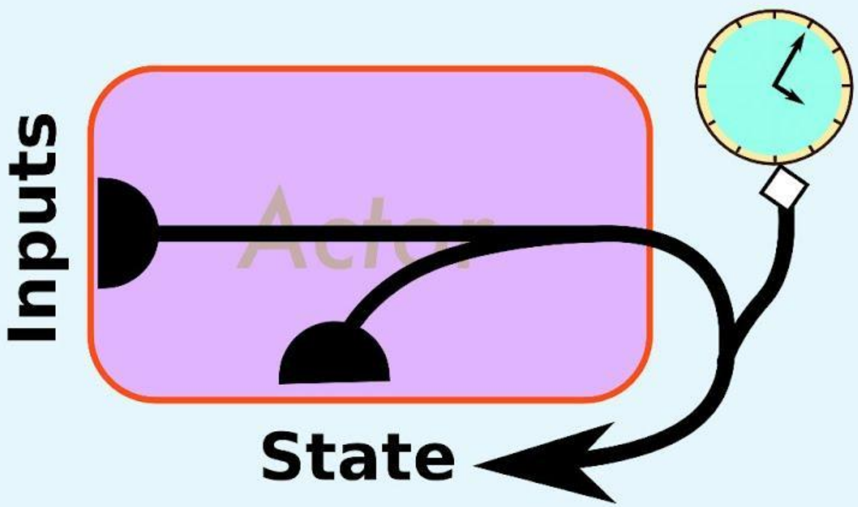


Updates to a new state
from inputs and state

Deadline

Determines a deadline for execution from inputs and state

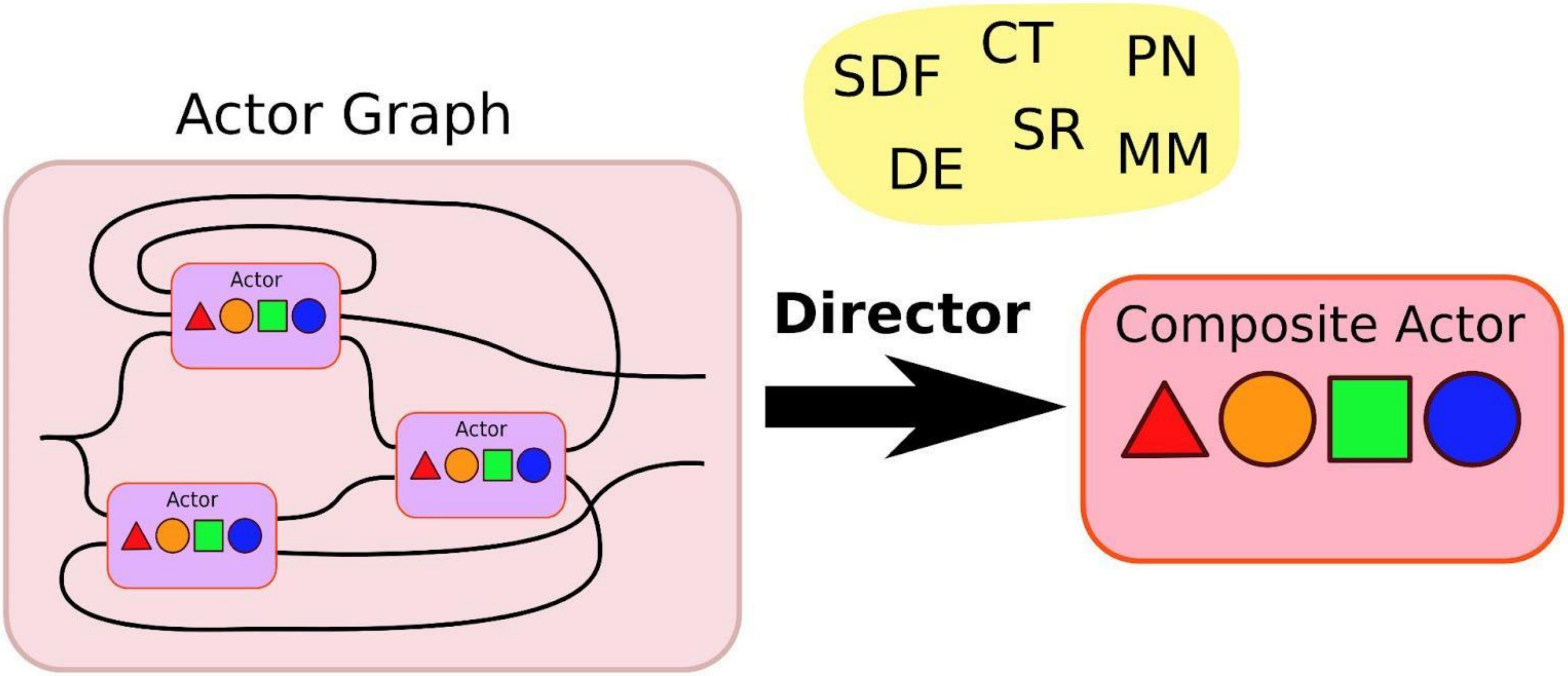




Timeupdate

Updates to a new state from inputs, state, and time

Directors Compose Actor Graphs into Actors



Directors compose the interfaces of Actors in a Model into those of the Composite Actor.

Mathematical Representations

The fixed-point semantics of SR can be understood in clear mathematical terms.

$$\left(\widetilde{F}_{s,x}(y)\right)(o) \quad = \quad F_j\left(s_j, (x, y) \restriction_{I_j}\right)(o)$$

Letting $y^*_{s,x}$ be the unique least fixpoint of $\widetilde{F}_{s,x}$.

$$\begin{aligned} F(s,x) &= y^*_{s,x} \restriction_O \\ P(s,x) &= \left(P_1\left(s_1, (x, y^*_{s,x}) \restriction_{I_1}\right), \ldots, P_n\left(s_n, (x, y^*_{s,x}) \restriction_{I_n}\right)\right) \end{aligned}$$

From "*A Modular Formal Semantics for Ptolemy*", Tripakis et al.

Coroutine Model of Computation

Theorem 1. *Given a non-strict Coroutine Model $\mathcal{M}$, if the input $\mathbb{I}_{\mathcal{M}}$ and output $\mathbb{O}_{\mathcal{M}}$ types of the model are finite-height pCPOs and operator $\oplus$ is monotonic, then the above recursive equations characterizing the kernel functions* $\mathbf{e}$ *and* $\mathbf{f}$ *have unique least fixed-point solutions in the partial order of functions with codomains $2^{\mathbb{G}}$ and $\mathbb{O}_M$, respectively.*

Theorem 2. *Given a non-strict Coroutine Model $\mathcal{M}$, if the input $\mathbb{I}_{\mathcal{M}}$ and output $\mathbb{O}_{\mathcal{M}}$ types of the model are finite-height pCPOs and operator $\oplus$ is monotonic, and if for each $q \in Q$ the functions $\mathbf{enter}_q$ and $\mathbf{fire}_q$ are monotonic in terms of $\mathbb{I}_q$, and the mapping functions $m_{\mathbb{I}}$ and $m_{\mathbb{O}}$ are monotonic, then the non-strict kernels* $\mathbf{e}$ *and* $\mathbf{f}$ *are continuous in terms of $\mathbb{I}_{\mathcal{M}}$.*

"*The Coroutine Model of Computation*", Shaver and Lee, 2012

I Conclude !

- Try out Ptolemy! It's open and free!
- Check out Modular Actor Interfaces.
- Feel free to design your systems modularly, hierarchically, and heterogeneously.
- http://ptolemy.eecs.berkeley.edu