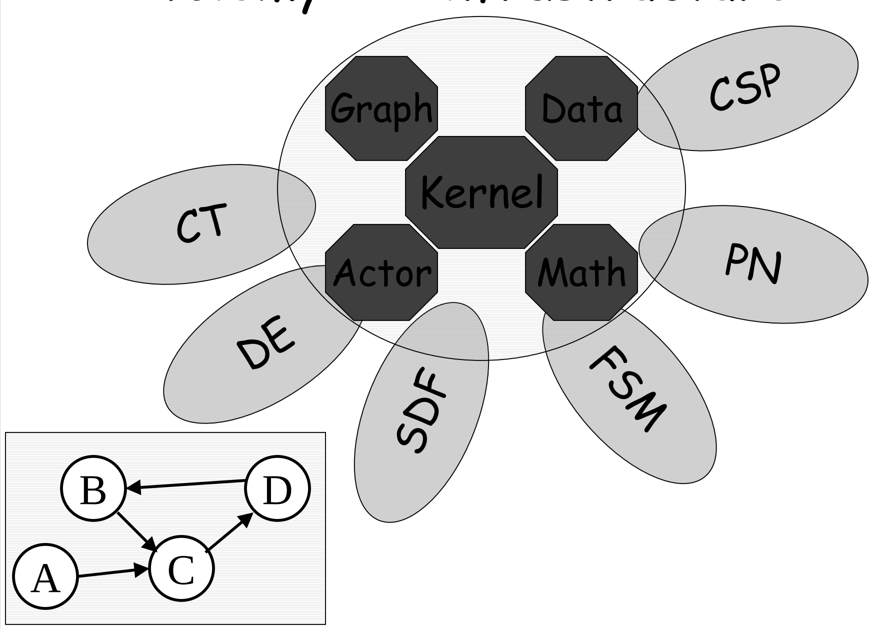
Hybrid System Simulation in Ptolemy II

Jie Liu, Xiaojun Liu, T. John Koo, Bruno Sinopoli, Shankar Sastry, and Edward A. Lee

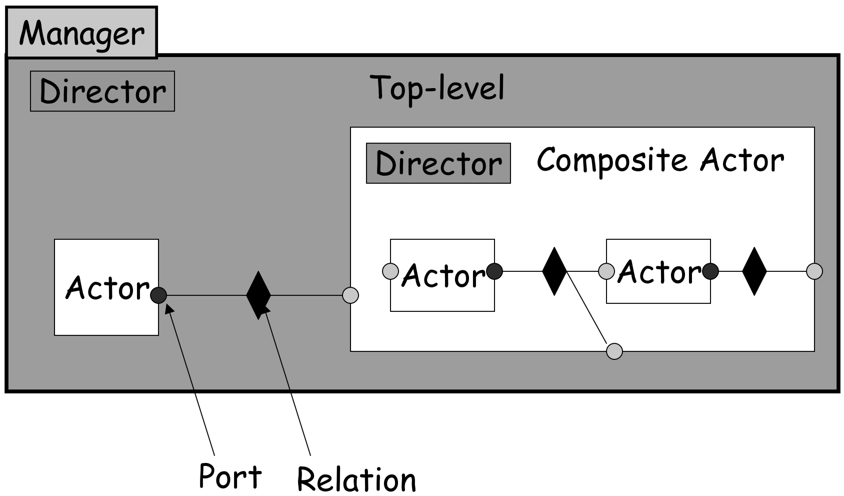
EECS, U.C. Berkeley

http://ptolemy.eecs.berkeley.edu

Ptolemy II Infrastructure



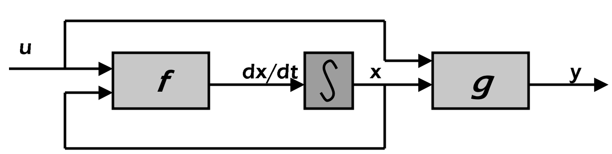
Kernel/Actor Packages



Modeling Continuous-Time Dynamics

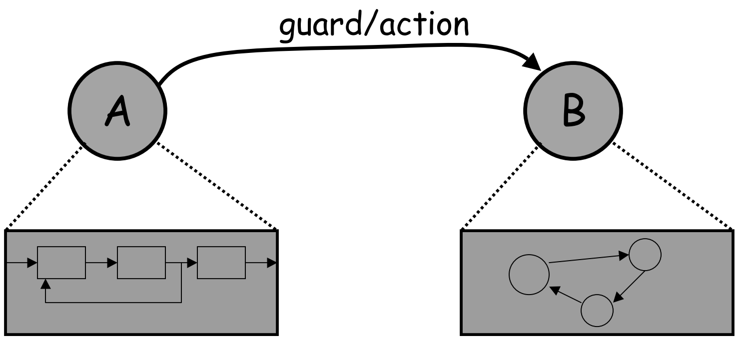
- ODE as Integrators with Feedback

$dx/dt = f(x, u, t), \quad x(t_0) = x_0$
$y = g(x, u, t)$



Modeling Hybrid Automata

- hierarchical states
- transitions
- guards/actions



Continuous Time Simulation

- Discretization of time
- Static scheduling, evaluate functions by actor firings.
- Fixed-point calculation.
- Various ODE solvers.
- Step size control
  - error tolerance
  - convergence
  - discontinuity
- Breakpoint handling
  - predictable breakpoints
    - register as discontinuous points
  - unpredictable breakpoints
    - refine step sizes to accurately find them

Interfacing Continuous and Discrete Dynamics

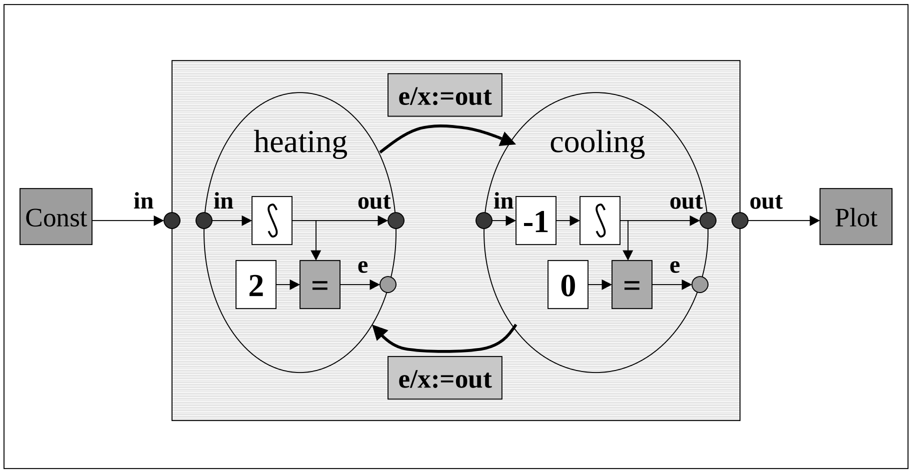
- Event Detection (C to D)
  - predictable events
    - event whose time is known beforehand
  - unpredictable events
    - refine step sizes to accurately locate them
- Event Interpretation (D to C)
  - zero-order hold
  - Dirac impulses

Continuous Subsystems Always Provide Discrete Interface

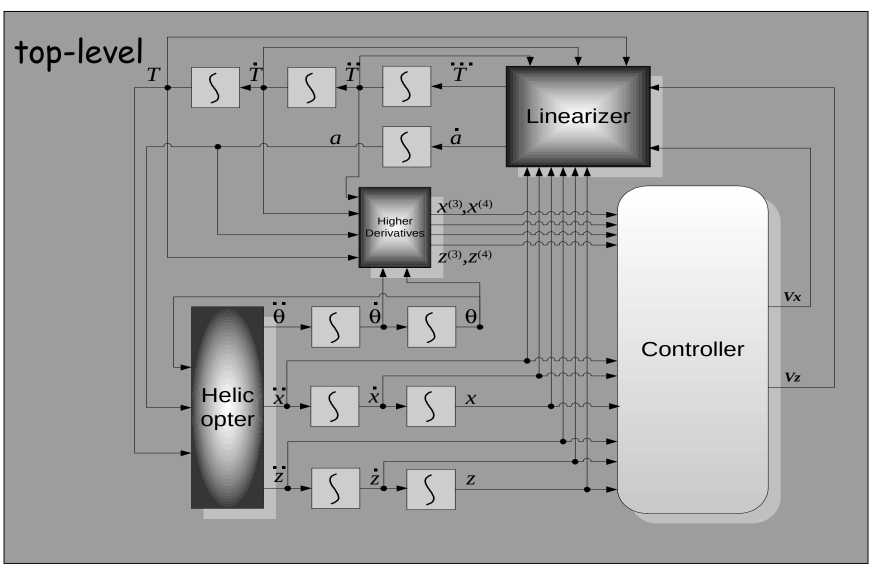
Hybrid Execution

- There is a current refinement in each state.
- A CT simulation finds the system behavior at discrete time points.
- At each time point, the FSM examines the output from the current refinement, and evaluates the guards.
- FSM makes transitions according to guard evaluations.
- FSM performs actions on the transition.

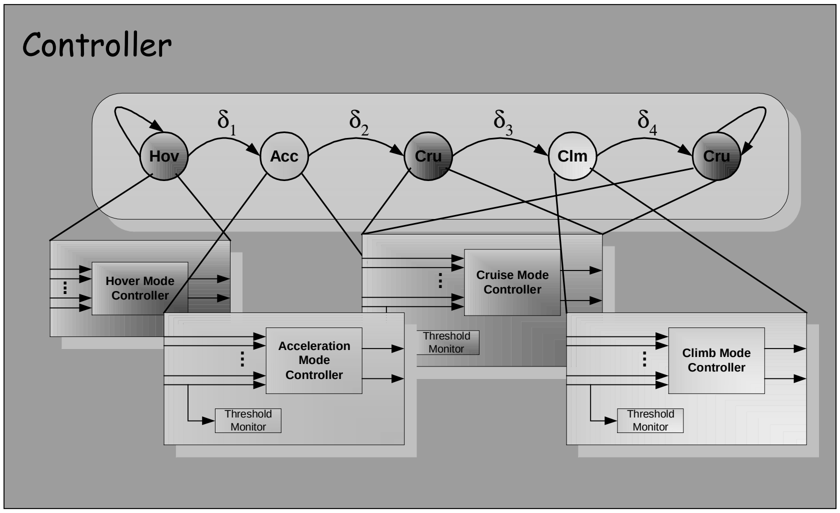
Example: Thermostat



Example: A 2D Helicopter Control



Example: A 2D Helicopter Control



Guards

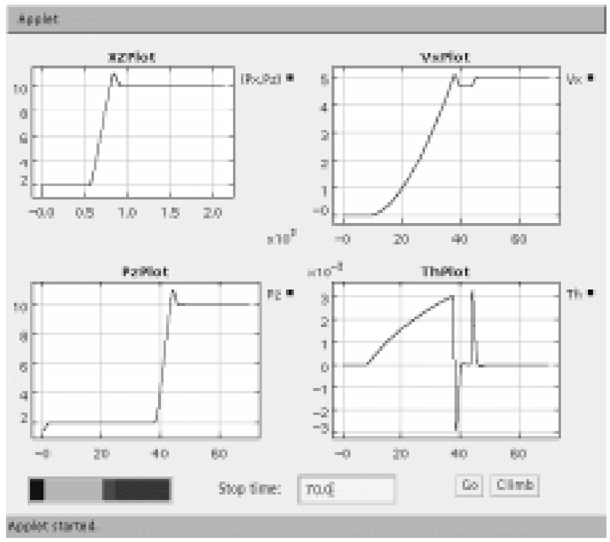
$\delta_1 : User\ Command$

$\delta_2 : (v \geq 5) \wedge (\left|Pz - C_z^p\right| < \varepsilon_z)$

$\delta_3 : (\left|v - 5\right| < \varepsilon_v) \wedge (\left|\gamma\right| < \varepsilon_\gamma), \quad where\ \gamma = \tan^{-1}(\frac{v_z}{v_x})$

$\delta_4 : (\left|Pz - C_z^p\right| < \varepsilon_z) \wedge (\left|v - 5\right| < \varepsilon_v)$

Result



For More Information

- http://ptolemy.eecs.berkeley.edu
- Ptolemy Group, “Heterogeneous Concurrent Modeling and Design in Java,” Technical Report UCB/ERL No. M98/72
- J. Liu, “Continuous-Time and Mixed-Signal Simulation in Ptolemy II,” Technical Report UCB/ERL No. M98/74
- J. Liu, X. Liu, etc, “Hierarchical Hybrid System Simulation,” (detail abstract) to appear in CDC’99, http://ptolemy.eecs.berkeley.edu/~liuj