Interoperation of Heterogeneous CAD tools in Ptolemy II

Jie Liu, Bicheng Wu, Xiaojun Liu,
Edward A. Lee
Dept. of EECS,
University of California, Berkeley

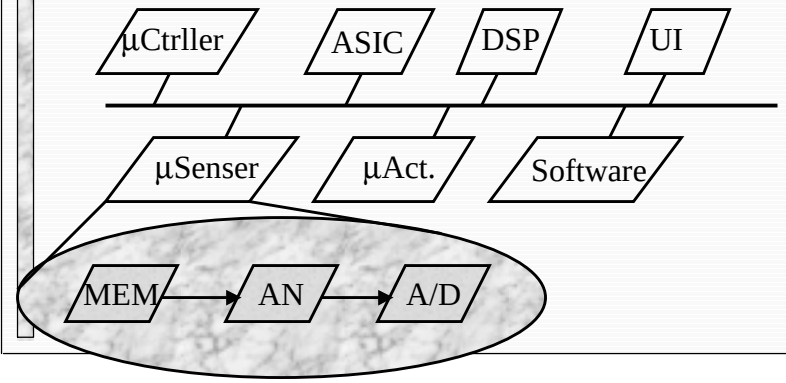
Symposium on Design Test and Microfabrication of MEMS/MOEMS, Paris, March 30 - April 1, 1999.

Outline

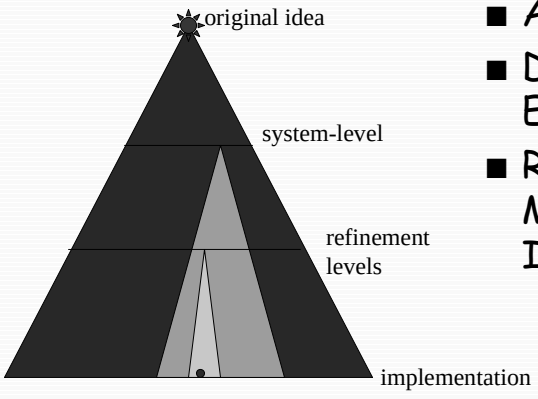
- Introduction
- Heterogeneous Design Methodology
- Semantics Study of Mixed-Signal Simulation
- Interoperation of CAD tools
- Example
- Conclusion

Complexity of MEMS Design

- MEMS are intrinsically complex
- MEMS are heterogeneous



Top-down Design Methodology



- Abstraction
- Design Space Exploration
- Retargetable Mapping to the Implementation

Heterogeneous Approach

- Models of Computation (MoC)

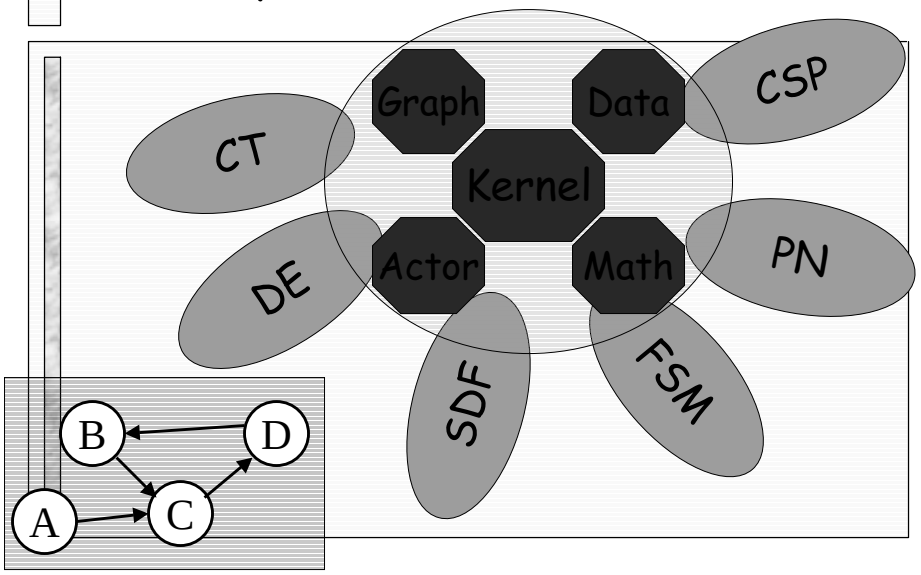
  "law of physics" that guides a domain of design

  - Continuous Time Models
    - PDE, ODE, physical components
  - Discrete Event Models
    - HDL, Embedded Software, Communication
  - Dataflow Models
    - DSP algorithms
  - Synchronous/Reactive Models
    - Embedded System

Heterogeneity of CAD tools

- Tools are designed based on MoCs
  - CT, DE, DF, SR …
- Interoperation of Tools
  - Sequentially applied in different stage of the design flow.
  - Concurrently applied in the context of co-simulation.

Ptolemy II Infrastructure

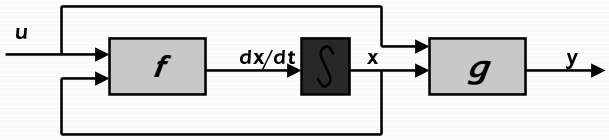


Continuous Time Modeling (1)

- Block Diagrams of ODEs

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

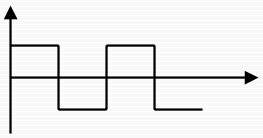
Integrators with Feedback Loops



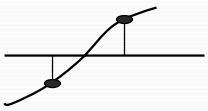
- Simulation
  - Discretization of time
  - Scheduling, evaluate functions by actor firings.
  - Fixed-point calculation.
  - Various ODE solvers.

Continuous Time Modeling (2)

- Breakpoint Handling .
  - Predictable Breakpoints:
    - known beforehand.
    - Register to a Breakpoint Table in advance.
    - Use breakpoints to adjust step sizes.

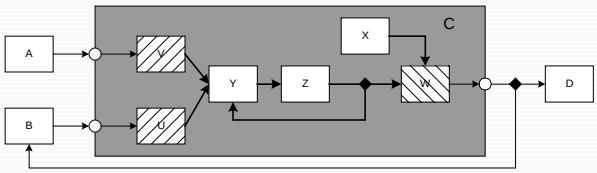


  - Unpredictable Breakpoints:
    - Prediction is not accurate enough.
    - Check after each integration step.
    - Refine the last step size if a breakpoint is missed.

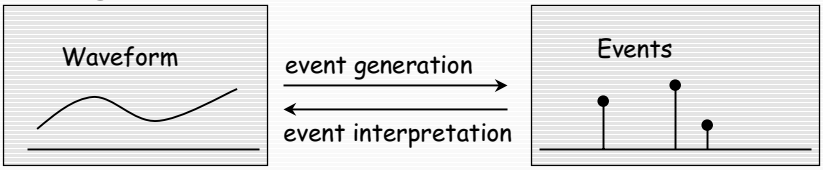


Mixed-Signal Modeling

- Container-Containee Relationship



- Signal Conversions



Execution: DE inside CT

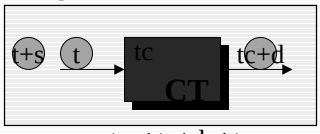
- Coordination
  - Next Event: predictable breakpoint.
  - DE subsystem should not be fired during the fixed-point iteration of the CT system.
- Two Phase Execution
  - event phase: DE executes, report next event time
  - continuous phase: solve ODEs till next breakpoint.

    The DE subsystem is only fired when there is an input event for it, or CT time = Next Event time
- t^--**t**-t^+ interpretation.

Execution: CT inside DE

- CT must run ahead of the DE (global) time!
  - CT subsystem must be causal

    $Te_{out} > Te_{in}$
  - CT can not jump in time
  - CT may generate event at any time



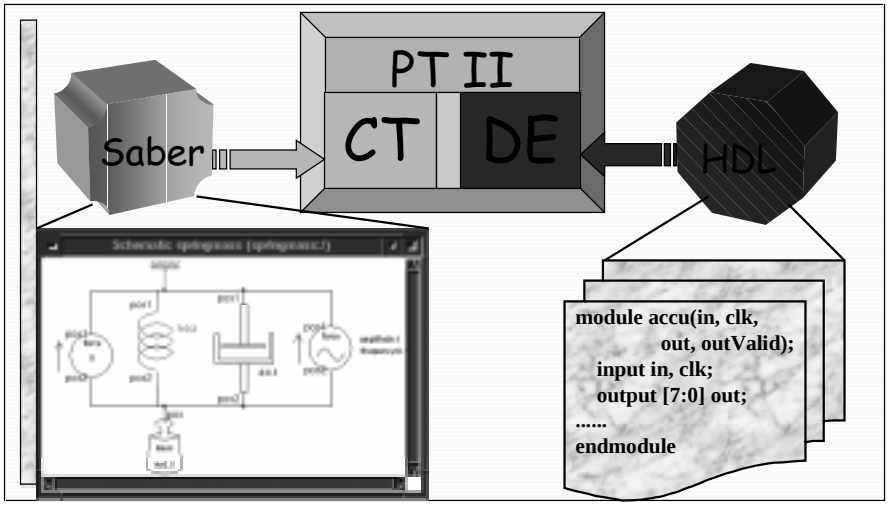
tc < tc+d < t

- CT must be able to rollback
  - If **tc** > **t** when CT is fired, it must rollback to **t**
- CT can not emit output events immediately
  - Detected event may not exist if there's another input event.

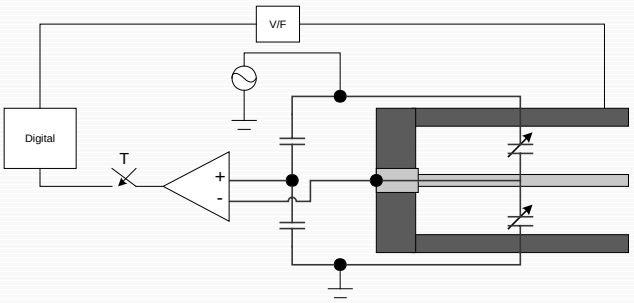
Summary

- Mixing MoC is not trivial.
- Not all CAD tools are designed with interoperation in mind.
  - event detection
  - execution sequence
  - roll back
- Ptolemy II can serve as the semantics glue.

Heterogeneous Tool Interactions

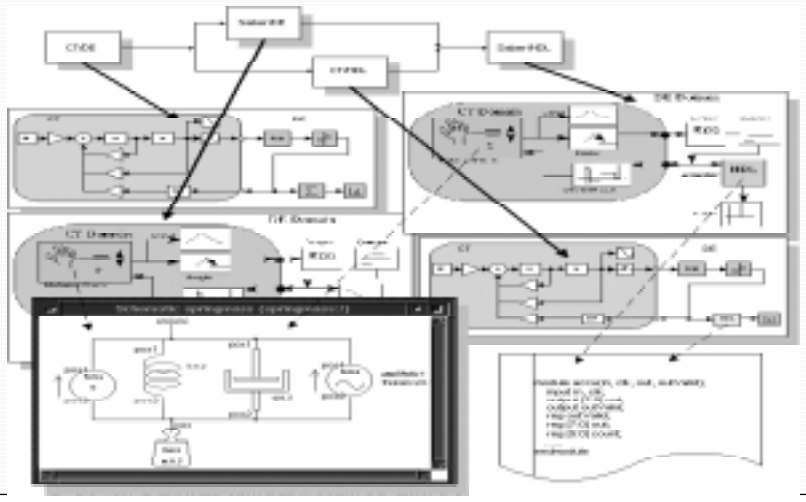


Example: Micro Accelerometer



M. A. Lemkin, “Micro Accelerometer Design with Digital Feedback Control”, Ph.D. dissertation, EECS, University of California, Berkeley, Fall 1997

Design Flow



Conclusion

- Heterogeneous Approach for Designing Complex Systems
- Semantics Study for Mixed-Signal Simulation
- Heterogeneous Tool Interaction
- For More Information:

http://ptolemy.eecs.berkeley.edu