

**Welcome
to
CS269: Hardware/Software
Engineering of Embedded Systems**

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HW/SW Engineering of Embedded Systems

- Class Meeting
 - SURGE 349
 - TuTh 12:40PM-2PM
- Prerequisite:
 - CS/EE 120A
 - consent of instructor
- Course number:
 - 16546
- 4 units, grades only
 - No S/NC, P/NP,...

Ingers Building Third Floor

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The solution

- The entire system must be designed as a whole
 - Hardware
 - Software
 - Interface
 - Memory
 - Peripheral
 - ...

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Implementation Architecture

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An Embedded System Application

Engine Control Unit

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Different Architectures

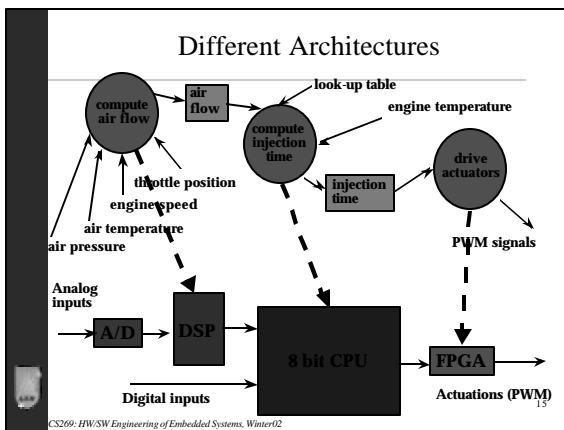
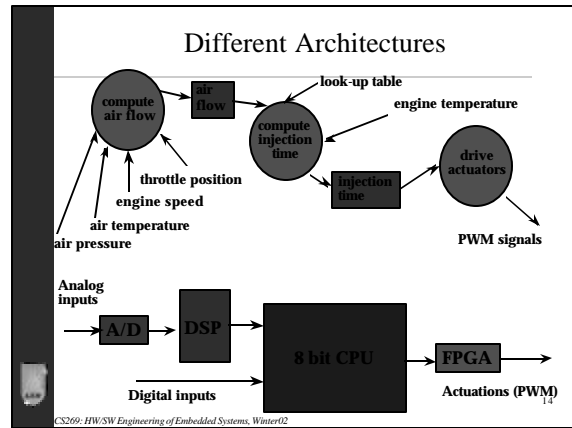
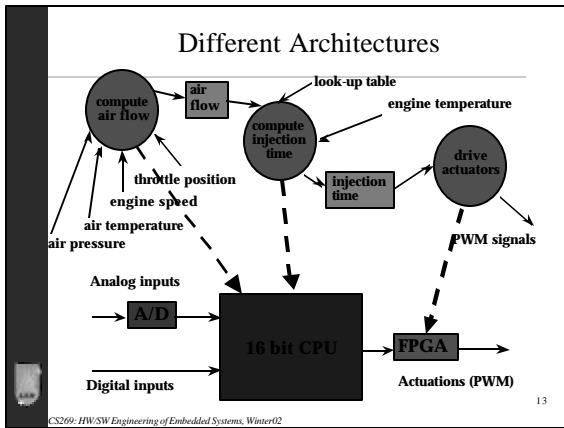
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Different Architectures

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Different Architectures

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Design Freedom

- Change architecture
- Change partitioning
- Change scheduling
- Change synthesis

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Current Industrial Practice

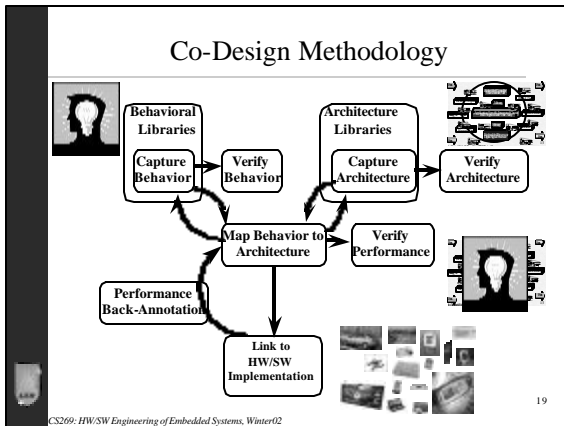
- Specify everything as ASIC
 - Offload as much as possible to processor
 - As long as timing constraints are met
- Specify everything as software
 - If timing constraints are violated
 - Move functionality to hardware
- System level partitioning
 - Implementations on different resources are proceed independently
 - "System Integration" at the end

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Problem with Current Approach

- Lack of unified system behavior representation
 - Can't verify the entire system
 - Lead to possible incompatibility across boundary
- *A priori* division into resources
 - Can't optimize across boundary
 - Lead to suboptimal design
- Lack of well defined design flow
 - Can't revise easily
 - Directly impact time to market

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Challenge for embedded system design (I.e. CS269)

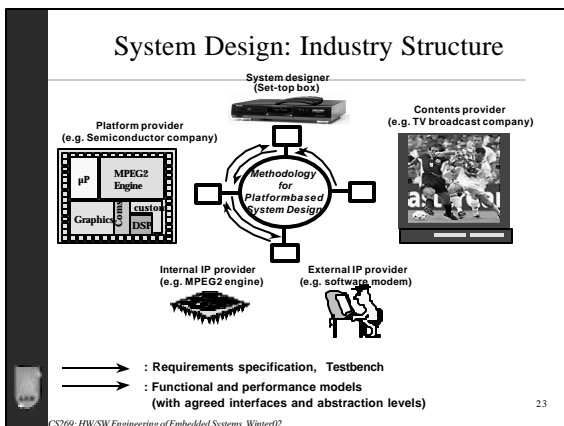
- How to specify?
 - Languages and models
 - VHDL, C, Java, FSM, PN, Matlab, ...
 - Framework (IDE)
- How to verify?
 - Prototype, simulation, co-simulation, formal verification, model-checking, theorem proving...
- How to synthesize/optimize?
 - Interface Synthesis
 - CAD Algorithm, Compiler Technology
 - Logic synthesis, BDD, ATPG, GNU
 - Architectural selection/Allocation, mapping
 - Scheduling/arbitration

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Metropolis

Design Environment for Heterogeneous Systems



Metropolis Project

- Approaches to complex embedded systems
 - Design Reuse
 - Time to market push
 - High level of abstraction
 - Exploit all possible design freedom
 - Concurrency
 - Application concurrency matching architectural concurrency
 - Heterogeneity
 - Automotive: block based/multi-CPU/safety/deadline
 - Wireless: sequential program/single-CPU/QoS/protocol

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Metropolis Project

- **Goal: develop a formal design environment**
 - **Orthogonalize concerns**
 - Computation vs communication (synthesized vs translated)
 - Function vs architecture (should vs could)
 - Behavior vs performance (abstract vs implemented)
 - Behavior vs constraints (abstract vs required)
 - **Have theoretical foundation**
 - Metamodel to represent different models of computation
 - Model vs language...
 - **Use Platform**
 - Software, hardware, system
 - With its implied communication structure

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Metropolis Project

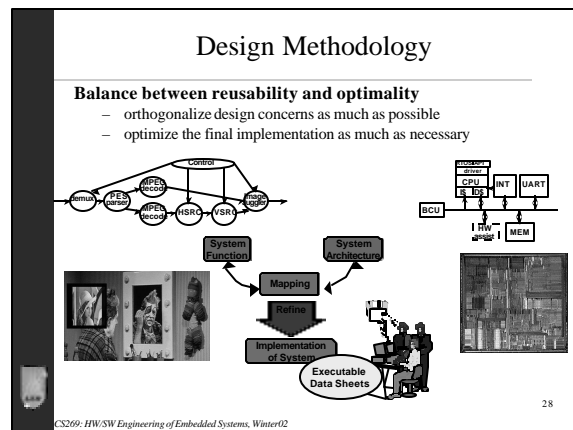
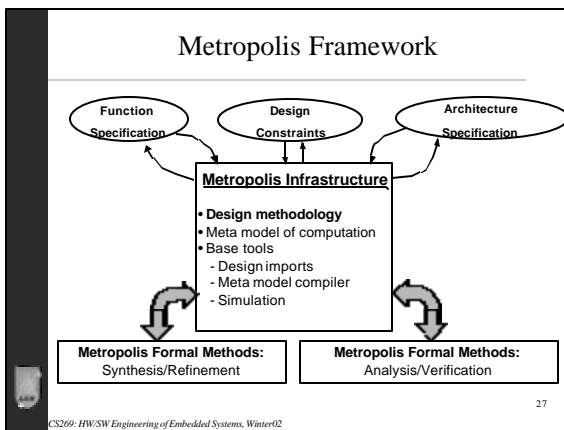
Participants:

- UC Berkeley (USA): methodologies, modeling, formal methods
- CMU (USA): formal methods
- Politecnico di Torino (Italy): modeling, formal methods
- Universita Politecnica de Catalunya (Spain): modeling, formal methods
- Cadence Berkeley Labs (USA): methodologies, modeling, formal methods
- Philips (Netherlands): methodologies (multi-media)
- Nokia (USA, Finland): methodologies (wireless communication)
- BWRC (USA): methodologies (wireless communication)
- BMW (USA): methodologies (fault-tolerant automotive controls)
- Intel (USA): methodologies (microprocessors)

- UC Riverside?

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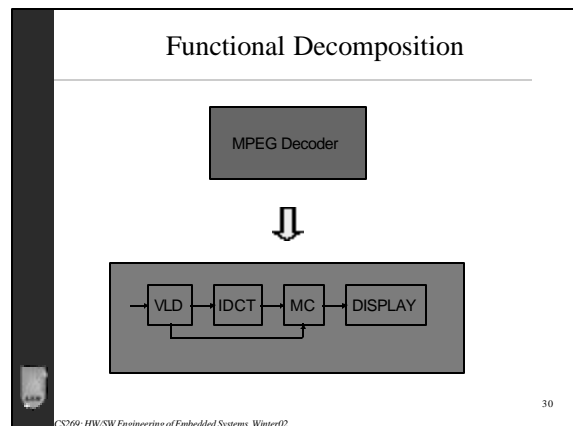


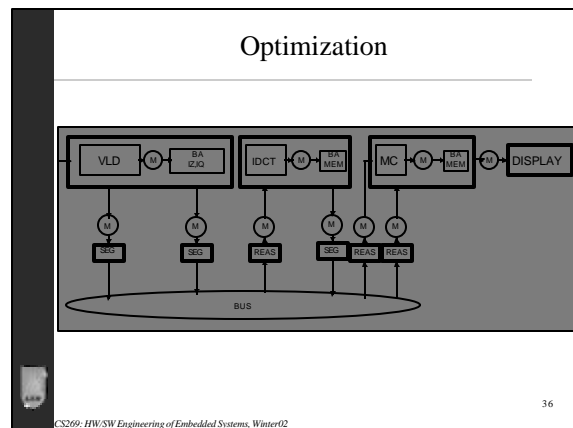
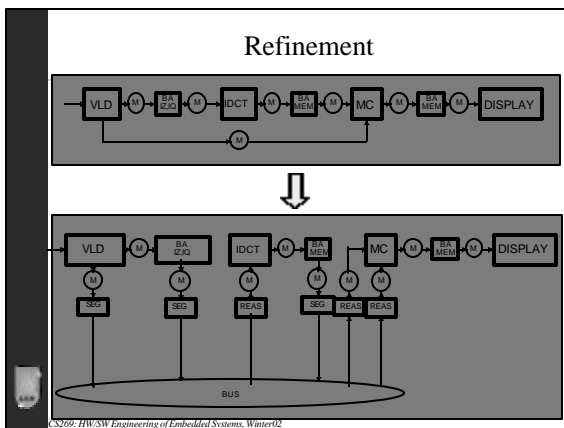
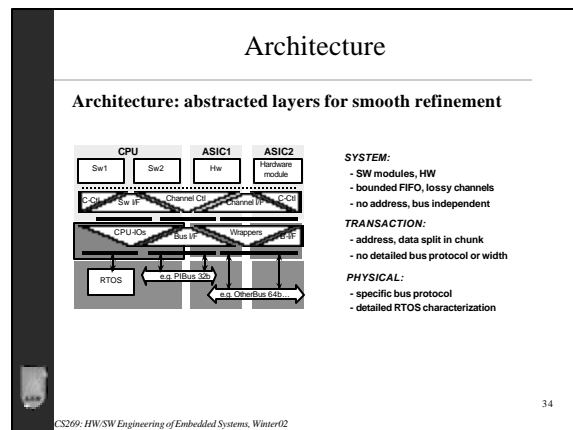
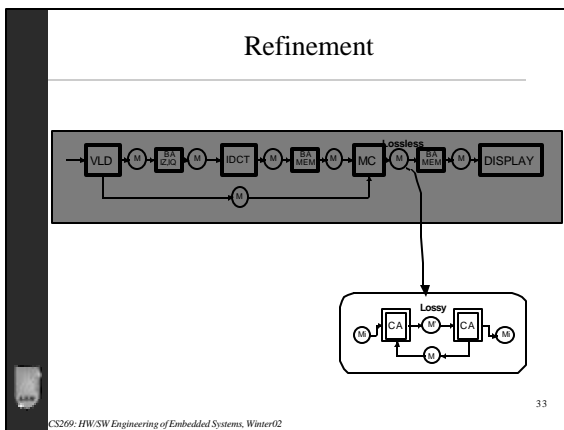
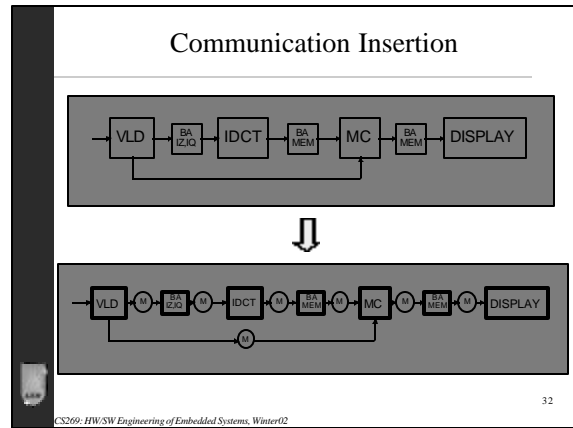
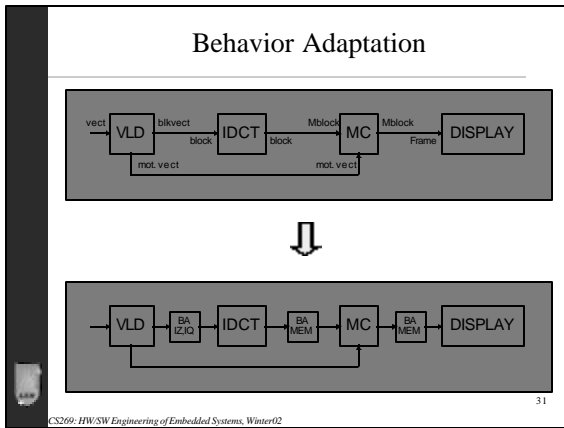
Design Methodology

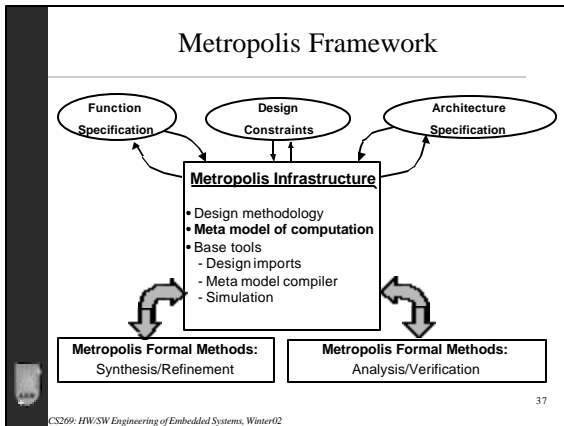
- Functional decomposition
- Behavior adaptation
- Media and MoC wrapper insertion
- Communication refinement
- Optimization

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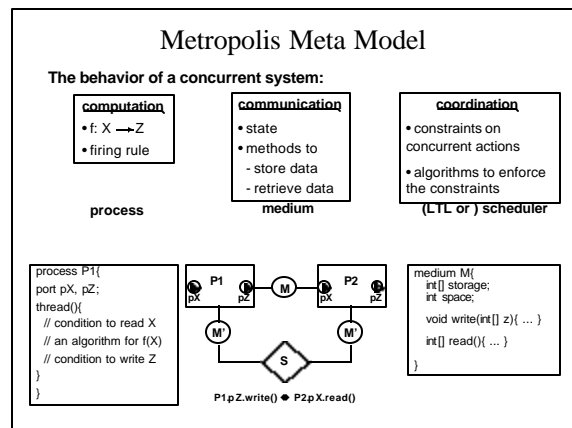
Metropolis Meta Model

- Do not commit to the semantics of a particular Model of Computation (MoC)
- Define a set of "building blocks":
 - specifications with many useful MoCs can be described using the building blocks.
 - unambiguous semantics for each building block.
 - syntax for each building block → language of the meta model.
- Represent behavior at all design phases; mapped or unmapped

Question: What is a good set of building blocks?

Metropolis Meta Model

- Processes, communication media, netlist
 - Describe functional requirement
- A mechanism of refinement
 - Replace process and medium by sublists of processes and media
- Temporal and propositional logics
 - Constraints

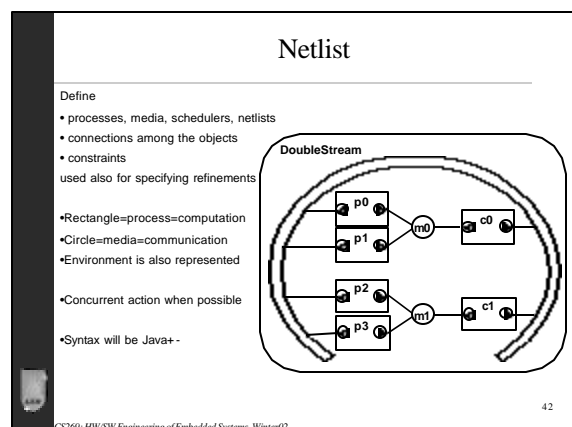


Slight digression

- Sentential logic
 - p, q
 - p ^ q, p v q, -p, p > q
- Linear Temporal Logic
 - Time is linear sequence of points
 - Gp: globally p
 - Fp: eventually p
 - Xp: next p
 - pUq: p until q
- Example:
 - Gp > Fp
 - What's always true is eventually true

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Why Java?

- Object orientation is here to stay
- C++ is yesterday's news
- What about inefficiency with interpreter?
 - Technology solution
 - Can always translate and compile
- <http://java.sun.com>
 - Official site, contain tutorial

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Process

- May declare fields and functions
- May be extended to define other processes
 - Object orientation a la Java and C++
- Fields and functions are private unless declared public
- Contain at least on constructor and a *thread* function
- Interact with other object through **port**
- **Port**
 - Special field of type *interface*
- **Interface**
 - Declare function with input/output type without implementing the m
- Process access port through calling interface functions

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An example process

```

process IntX {
port IntReader port0;
port IntWriter port1;

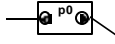
IntX(){

void thread() {
int x;
while(true) {
Rd: x=port0.readInt();
Wr: port1.writeInt(x);
}}
    
```

```

interface IntReader extends Port {
update int readInt();
eval int n();
}

Interface IntWriter extends Port {
update void writeInt(int data);
eval int space();
}
    
```

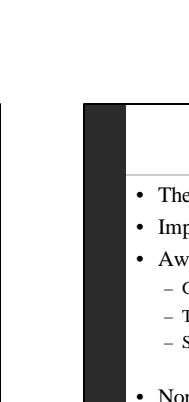


- Update
 - Function may change the state of media that implements the interface
- Eval
 - Function may NOT change the state of the media...

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Medium

- Implements interfaces by providing code for the function of the interfaces
- May define fields and functions



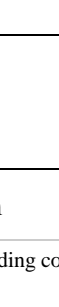
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An example medium

```

Medium IntM implements IntWriter, IntReader, IW, IR, IC, IS, IN {
int storage, space, n;
IntM () { space = 1 ; n = 0 ; }
update void writeInt(int data) {
await ( space > 0 ; this.IW , this.IS ; this.IW )
await ( true ; this.IC , this.IS , this.IN ; this.IC ) {
space = 0 ; n = 1 ; storage = data;
}
}
update int readInt() {
await ( n > 0 ; this.IR , this.IN ; this.IR )
await ( true ; this.IC , this.IS , this.IN ; this.IC ) {
space = 1 ; n = 0 ; return storage;
}
}
eval int space() {await(true:this.IW,this.IC;this.IS) return space;}
eval int n() {await(true;this.IR,this.IC;this.IN) return n;}
}

interface IW extends Ports {
interface IR extends Ports {
interface IC extends Ports {
Interface IS extends Ports {
}
}
}
}
    
```



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await

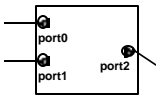
- The only construct in metamodel for synchronization
- Implement critical sections
- Await (guard ; test list; set list){critical section}
 - Guard: condition that must hold for execution to continue
 - Test list: other process should not have set these
 - Set list: other process can not set these now
- Nondeterminism
 - Await{ (g1 ; t1 ; s1) c1 , (g2 ; t2 ; s2) c2... }

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Another example process

```
Process Y {
  port IntReader port0;
  port IntReader port1;
  port IntWriter port2;
  ...
  void thread() {
    int z;
    while (true) {
      await {
        (port0.n() > && port1.n() > 0;
        port0.IntReader, port1.IntReader;
        port0.IntReader, port1.IntReader)
        { z = foo(port0.readInt(), port1.readInt()); }
      }
      port2.writeInt(z);
    }
  }
  int foo(int x, int y) { ... }
}
```

dataflow style



The diagram shows a rectangular block representing a process. On the left side, there are two input ports labeled 'port0' and 'port1', each with a small circle and a line extending to the left. On the right side, there is one output port labeled 'port2', with a small circle and a line extending to the right. An arrow labeled 'dataflow style' points from the text to the 'await' block in the code above.

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