Other Tools and their relevance to Metropolis

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Outline

- Fresco
- Mescal
- Ptolemy II
- VCC
- SystemC
- UML
- Conclusions

09/06/2000 2

The FRESCO Group

- Formal REaltime Software COmponents
- Methodology
  - Masaccio
    - top level formal specification of continuous time and discrete time systems
  - Pure Giotto
    - Abstract time triggered programming
  - Annotated Giotto
    - Mapped and constrained Giotto
  - *The E-Machine*
    - a tool for supporting giotto

Methodology

Masaccio
↓
Pure Giotto
↓
Annotated Giotto
↓
The E-Machine

09/06/2000 3

Masaccio

- Formal framework for embedded system description
  - Hardware and Software
  - All components are non-deadlocking
- Continuous and Discrete Time
- Hierarchical
  - Parallel composition
  - Serial composition
- Provable refinement
  - Supports Assume-Guarantee reasoning

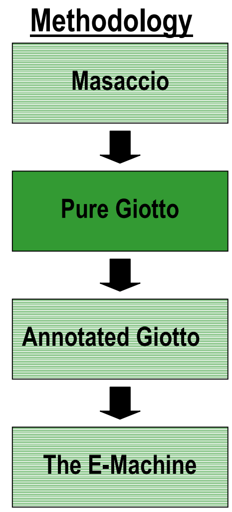
Methodology

Masaccio
↓
Pure Giotto
↓
Annotated Giotto
↓
The E-Machine

09/06/2000 4

Pure Giotto

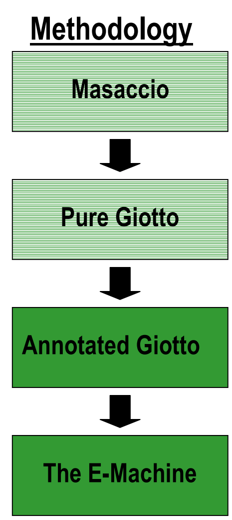
- Time Triggered Programming (MOC)
- Abstract Description
- Instantaneous Communication
- Time-Deterministic Computation
- Different Components
  - Modes
  - Tasks
  - Ports
    - sensors, actuators, mode switch, private
  - Drivers – connections between ports



09/06/2000 5

Refined Giotto & the E-machine

- Refine from pure Giotto down to an implementation
- Generate code runnable on the specified platform.
- 3 phases of refinement
  - Giotto-P – **Platform is specified. With hosts, nets, and worst case execution times.**
  - Giotto-PM – **Mapping is specified.**
  - Giotto-PMS – **Scheduling of the resources is added.**
- The E-machine (the embedded machine)
  - Scheduling machine for control tasks
  - Based on timers/counters and a stack
  - Interface to an RTOS and Giotto



09/06/2000 6

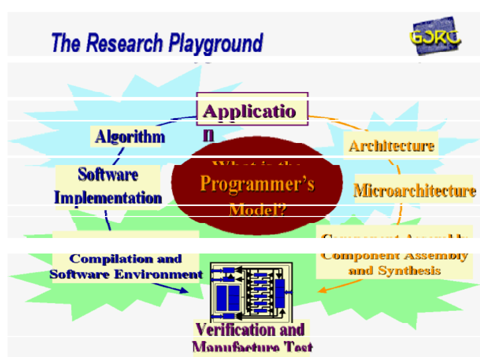
Fresco Conclusions

- Pro's
  - Formalism (Provable performance), Hierarchy, Composition, and Refinement.
  - Tools are mostly completed (e-machine still new)
  - Addresses discrete + continuous time domains
- Con's
  - Restricted to developing time triggered control software
  - Assumptions made may be too restrictive
- Relevance to Metropolis
  - Formalism and Hierarchy are nice
  - Great work on provable WCET

09/06/2000 7

The Mescal Group

- Modern Embedded Systems: Compilers, Architectures, and Languages
- Focus on highly programmable heterogeneous multiprocessor embedded system platforms
  - Currently driven by network processors
- Main views
  - Application
  - Architecture
  - Programmer's Model



The Methodology Picture*

09/06/2000 *Portions taken from 12/00 Mescal GSRC presentation 8

Mescal Architecture

- Design exploration
- Single Processing Element
  - VLIW blocks
  - Formal model
  - Automatic generation of compiler and simulator
- Memory Architecture
  - Based on database access model
- Communication Architecture
  - OSI protocol stack
- Visualization and Simulation currently uses Ptolemy II
  - In the future use Liberty (Princeton)

09/06/2000 9

Mescal Application

- Extract Maximal Parallelism
  - Process Level
  - Thread Level
  - Instruction Level
  - Bit Level
- Driven by Network Processor Applications
  - Super exponential growth
  - Many features being added
  - Application Profiling (currently MPLS)
    - Evaluate various processors and determine what arch. features are useful

09/06/2000 10

Mescal Programmer's Model

- What the programmer sees
  - Hide unnecessary details
  - Reveal useful details
- Model of computation
  - Not necessarily formal
  - Application Dependent
    - Currently working on the Click Network Router and its semantics
      - Push/Pull semantics
  - Much discussion ongoing

09/06/2000 11

Long Term Mescal Goals

- Flexible Architectural Environment
  - Support Multiple Levels of Concurrency
- Automatic generation of SW environment
  - Simulators
  - Retargetable Compilers/Assemblers/Debuggers
  - Run time environment
- Analysis Tools

09/06/2000 12

Mescal Conclusions

- Pro's
  - Automatic SW environment generation
  - Architectural exploration techniques
  - Seems great for programmers
- Con's
  - Still in early stages of development
  - Takes a limited view of hardware
- Relevance to Metropolis
  - Mostly Bottom-Up approach (vs. Top-Down-ishness of Metro)
  - Software oriented approach
  - Nice complement to Metro

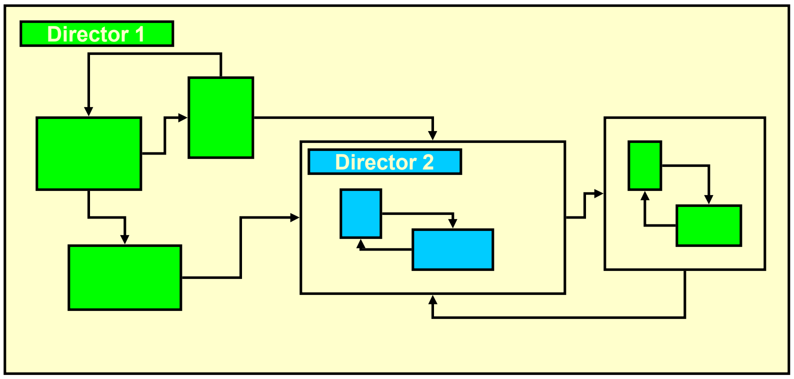
09/06/2000 13

Ptolemy II (UC Berkeley)

- Component-based simulator
  - components interact with producer-consumer semantics
- Supports several models of computation
- Hierarchical Heterogenity
  - each level of the hierarchy must use a single model
  - heterogeneity only possible at the boundaries
- Methodology
  - choose a model for each object
  - mix models hierarchically
  - create reusable models (polymorphism)

09/06/2000 14

Hierarchical Heterogeneity



09/06/2000 15

Ptolemy Meta-Model

- Abstract syntax based on a network of components
  - Actors are connected through ports and relations
- Actors expose an execution API:
  - preinitialize( );
  - initialize( );
  - prefire( );
  - fire( );
  - postfire( );
  - wrapup( );
  - terminate( );
- Composite actors characterized by a director

09/06/2000 16

Ptolemy execution model

- The *director* defines the execution semantics of a composite actor (one level of hierarchy)
- A lower level director is treated as an actor
  - with the additional transfer of data to/from the higher level
- An execution is a sequence of iterations
  - preceded by initialization
  - followed by wrapup
- During each iteration the director calls the fire methods of the controlled entities
  - (prefire( ), fire( )*, postfire( ))*

09/06/2000 17

Ptolemy data transfer

- Ports expose a data communication API
  - put( );
  - get( );
  - hasRoom( );
  - hasToken( );
- A *receiver* in each port defines the semantics of the communication
  - by sequencing the calls to the communication API
  - by suspending the execution when appropriate
- A director and a receiver define the model of computation

09/06/2000 18

Ptolemy II Conclusions

- Pro's
  - Robust software infrastructure
  - Heterogeneous systems
  - Flexible meta-models supports several domains (including fixed-point semantics)
  - Separation of communication protocols from the actor description
- Con's
  - Limited to hierarchical model composition
  - Domains not completely formally defined
  - Lack of architectural exploration, refinement, implementation
- Relevance to Metropolis
  - Environment for experimentation on heterogeneous design
  - Possible underlying simulation engine

09/06/2000 19

VCC (Cadence)

- Virtual component integration
- Architecture exploration
- Separation of functionality and architecture
- Functional simulation
- Performance simulation through mapping
- Underlying discrete event model of computation

09/06/2000 20

VCC functionality

- Blackbox
  - simulation model
- Whitebox
  - performance estimation
  - simulation model
- Clearbox
  - synthesis
  - performance estimation
  - simulation model

09/06/2000 21

VCC architecture

- Predefined architecture blocks for computation and communication
  - ASIC
  - CPU
  - OS
  - data bus, interrupt bus
- Predefined communication patterns
  - interrupt, polling, shared memory, etc.
- Flexibility using Architectural Services
  - provide performance simulation model
  - ability to model at several levels of details
  - dynamic binding for mapping independence

09/06/2000 22

Performance modeling

- Delay scripts
  - Relative timing of input to output, including some data dependency
- Annotated blackbox/whitebox
  - Flexible in-line annotation for higher accuracy
- Software estimation
  - High-level processor models for fast performance estimation
- Specialized architectural services
  - Flexible architectural modeling tool for arbitrary trade-off of speed vs. accuracy
- Not just timing models!

09/06/2000 23

VCC Links to Implementation

- Customizable exporters
- Automatic synthesis of communication infrastructure
  - register mapping
  - memory allocation
  - interrupt service routine
  - operating system calls

09/06/2000 24

VCC conclusions

- Pro's
  - Architectural exploration with performance estimation
  - Fast simulation
  - Software and communication synthesis
- Con's
  - Single model of computation
  - No hardware synthesis
- Relevance to Metropolis
  - Separation of functionality and architecture
  - Advanced architectural modeling capabilities
  - Communication patterns
  - Support for Operating System modeling

09/06/2000 25

SystemC 1.0

- Extension of C++ with modules, ports and signals
- HW-like data types, including fixed-point types
- Model
  - discrete event with delta cycles
  - processes react to changes in signals (sensitivity list)
- Abstraction close to that of RTL hardware description languages

09/06/2000 26

SystemC 2.0

- An attempt to raise the level of abstraction to the system level
- Introduces new concepts
  - channels: container for communication and synchronization
  - interfaces: set of access methods for a channel
  - events: low-level synchronization primitives
- Can model HW signals, queues, semaphores, memories, busses, etc.

09/06/2000 27

SystemC 2.0 model

- 64-bit unsigned integer absolute global time
- Supports static sensitivity list as in 1.0
- Supports event based synchronization
  - wait(event || time stamp);
  - event.notify(<time>);

09/06/2000 28

SystemC 2.0 execution model

- Execution phases:
  - initialization, ((evaluate*, <update>)*, advance)*
- Based on co-routines and independent stacks for each process
- Order of execution of processes in the evaluate phase is unspecificied
- Processes can only be preempted when they call wait( )
  - Atomicity of execution is guaranteed between wait( )'s
- To model preemption, must include effects of delays in the architecture using wait( )

09/06/2000 29

SystemC 2.0 comm. model

- Interfaces define a set of access methods
- Channels implement one or more interfaces
  - primitive: have no structure and do not access other channels
  - hierarchical: are modules that can access other modules and channels
- The interface method is executed by the channel in the context of the caller
- Use the "request-update" scheme for complex synchronizations
- Communication refinement
  - Adapter insertion: convert the interface from abstract and refined
  - Interface refinement: merge adapters into processes (aka "protocol in-lining")

09/06/2000 30

SystemC 2.0 Conclusions

- Pro's
  - Industry standard (potential for wide adoption and tools)
  - Supports communication refinement
- Con's
  - No architectural modeling
  - No software modeling
- Relevance to Metropolis
  - Target simulation environment
  - Similar concepts of separation between processes and communication media

09/06/2000 31

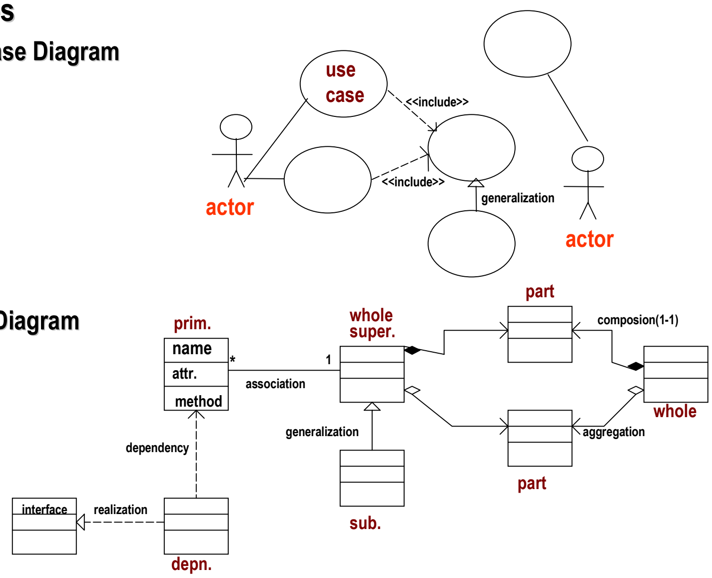
UML

- A standard adopted by OMG for SW specification
- A language designed to model, NOT to implement
  - good for system specification
  - limited in defining contents of actions
  - insufficient to support testing, simulation, code generation
- Diagrams
  - Use case diagrams (graphical/textual)
    - represent functional requirements
  - Class diagrams
    - show the static structure of the system
  - State diagrams
    - show how objects transit from one state to another
  - Other diagrams
    - activity diagrams, physical diagrams, interaction diagrams, package diagrams ...

09/06/2000 32

UML

- **Examples**
  - Use Case Diagram
  - Class Diagram



09/06/2000 33

UML

- **Pro's**
  - clearly specified syntax
  - expressed in multiple visual/textual diagrams
  - extensible mechanism
- **Con's**
  - vaguely defined semantics
  - translation from syntax to semantics not precisely defined
- **Relevance to Metropolis**
  - can be applied to a wide range of applications
  - can serve as a very good front end description of Metro
    - well defined syntax
    - can describe syntax for any MOC
    - UML-> Metro IF needs to be done

09/06/2000 34

Summary

- **FRESCO**
  - Formal design with an emphasis on time-triggered software
- **Mescal**
  - Focus on software for highly programmable embedded platforms
- **Ptolemy II**
  - Modeling of heterogeneous systems
- **VCC**
  - Architecture exploration, perforamance estimation
- **SystemC**
  - Separation of communication and computation.
- **UML**
  - Specification and documentation of system structures

09/06/2000 35

Questions Raised

- How can we get these different tools to work together?
- Should we get them to work together?
- What are the strengths and weaknesses of these tools? Of Metropolis?
- Have we missed anything?
  - Tools?
  - Observations?

09/06/2000 36