Ptolemy Ptutorial

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Agenda (Morning)

8:30

1. Overview of the Ptolemy project (45 minutes) — Lee
2. Guide to the GUI (30 minutes) — Evans
3. Higher-Order Functions (15 minutes) — Evans

10:00 — Break

10:15

4. Dataflow models of computation (30 minutes) — Lee
5. The synchronous dataflow domain (15 minutes) — Lee
6. Writing custom stars for the SDF domain (15 minutes) — Lee
7. Boolean and dynamic dataflow domains (15 minutes) — Lee

11:30

8. The discrete-event domain (30 minutes) — Evans

12:00 — Lunch

Agenda (Afternoon)

1:30

9. Writing Tcl/Tk blocks (15 minutes)	Lee
10. Code generation concepts (30 minutes)	Williamson
11. Writing blocks for the CGC and VHDL domains (45 min.)	Williamson

2:45 — Break

3:15

12. Defining Targets (15 minutes)	Lee
13. Defining Domains (30 minutes)	Wilson
14. Interfacing to foreign design environments (30 minutes)	Wilson
15. Debugging (15 minutes)	Lee
16. Preview of Coming Attractions (15 minutes)	Lee

5:00 Adjourn

Ptolemy as a Tool and as a Laboratory

Ptolemy is

- Extensible
- Publicly available
- An open architecture
- Object-oriented

Allows for experiments with:

- Models of computation
- Domain-specific tools
- Design methodology
- Software synthesis
- Hardware synthesis
- Cosimulation
- Codesign

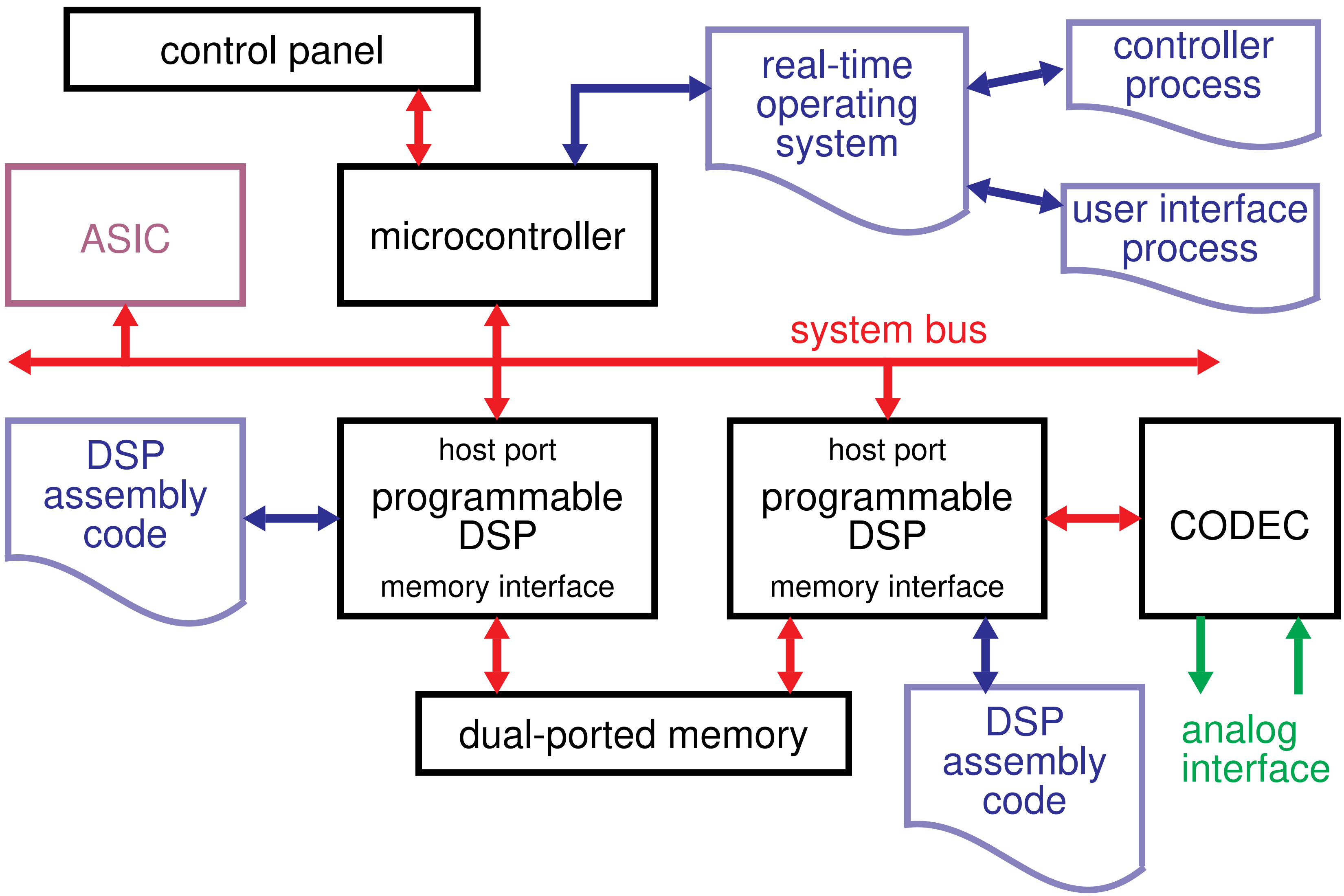
Rationale for heterogeneity: specialized models are

- More useful to the system-level designer
- More amenable to hardware and software synthesis.

Major Activities

- **Formal methods**
  - **Dataflow** (process networks, synchronous, Boolean, multidimensional, ...)
  - **Control** (hierarchical FSMs, Esterel, synchronous languages, ...)
  - **Partitioning and scheduling of dataflow graphs** (optimize IPC, memory, ...)
  - **Programming languages** (higher-order functions, polymorphism, ...)
- **Algorithm-level design methodology**
  - **Mixing models of computation** (discrete-event, FSMs, dataflow, imperative, ...)
  - **Animation and design visualization** (Tcl/Tk, Matlab, xv, ...)
  - **Mixing domain-specific tools** (filter design, Matlab, Mathematica, ...)
  - **Visual programming** (dataflow, FSMs, regularity, recursive, functional, ...)
- **System-level design methodology**
  - **Synthesis of embedded software** (high-level, assembly, ...)
  - **Design complexity management** (data, tool, flow, methodology, ...)
  - **Hardware/software codesign** (DesignMaker, GCLP partitioning, ...)
  - **Architecture design and performance modeling** (OT principle, VHDL, ...)

Typical Embedded Signal Processing System



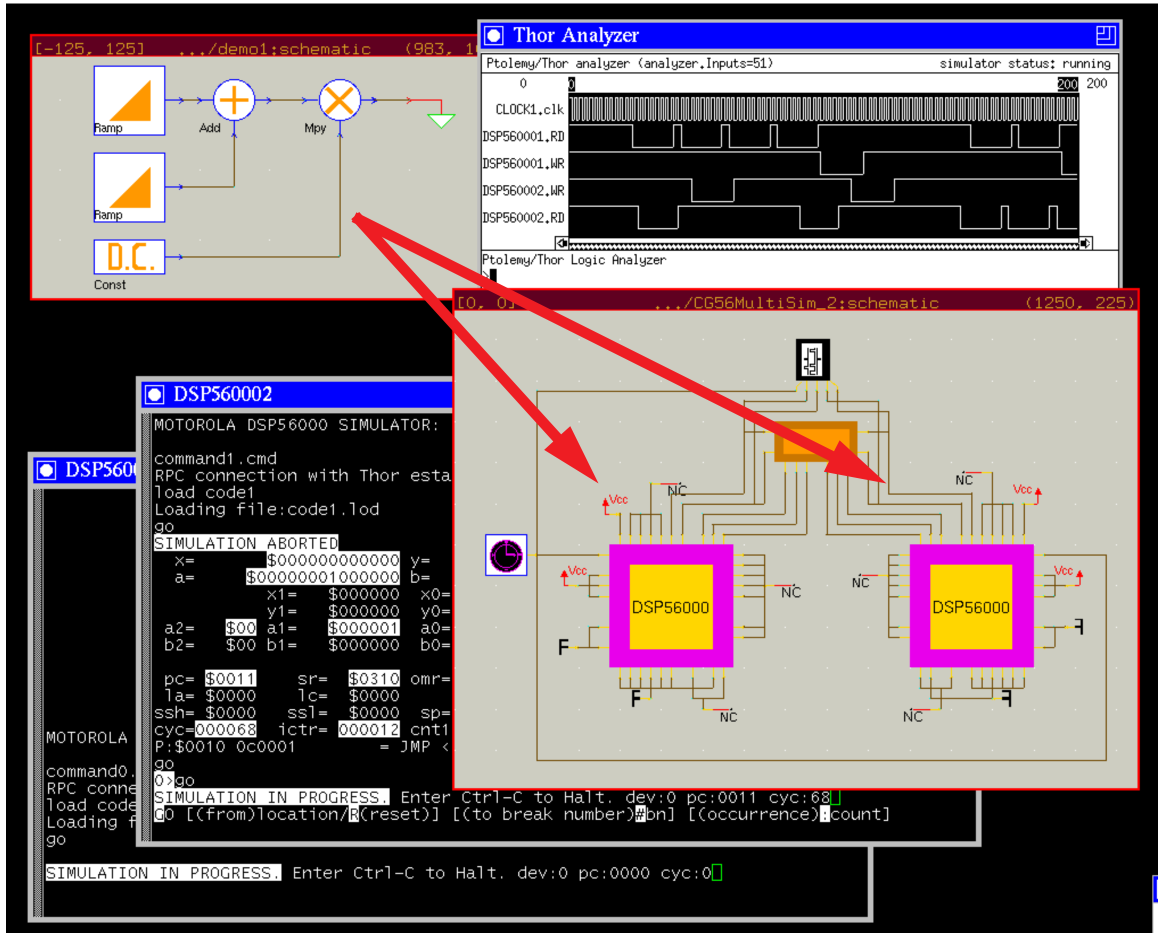
Baseline Cosimulation

Features Today

- Instruction set model of the processor.
- RTL model of chip input/output.
- High-level software development.
- Compatibility with ASIC simulators.

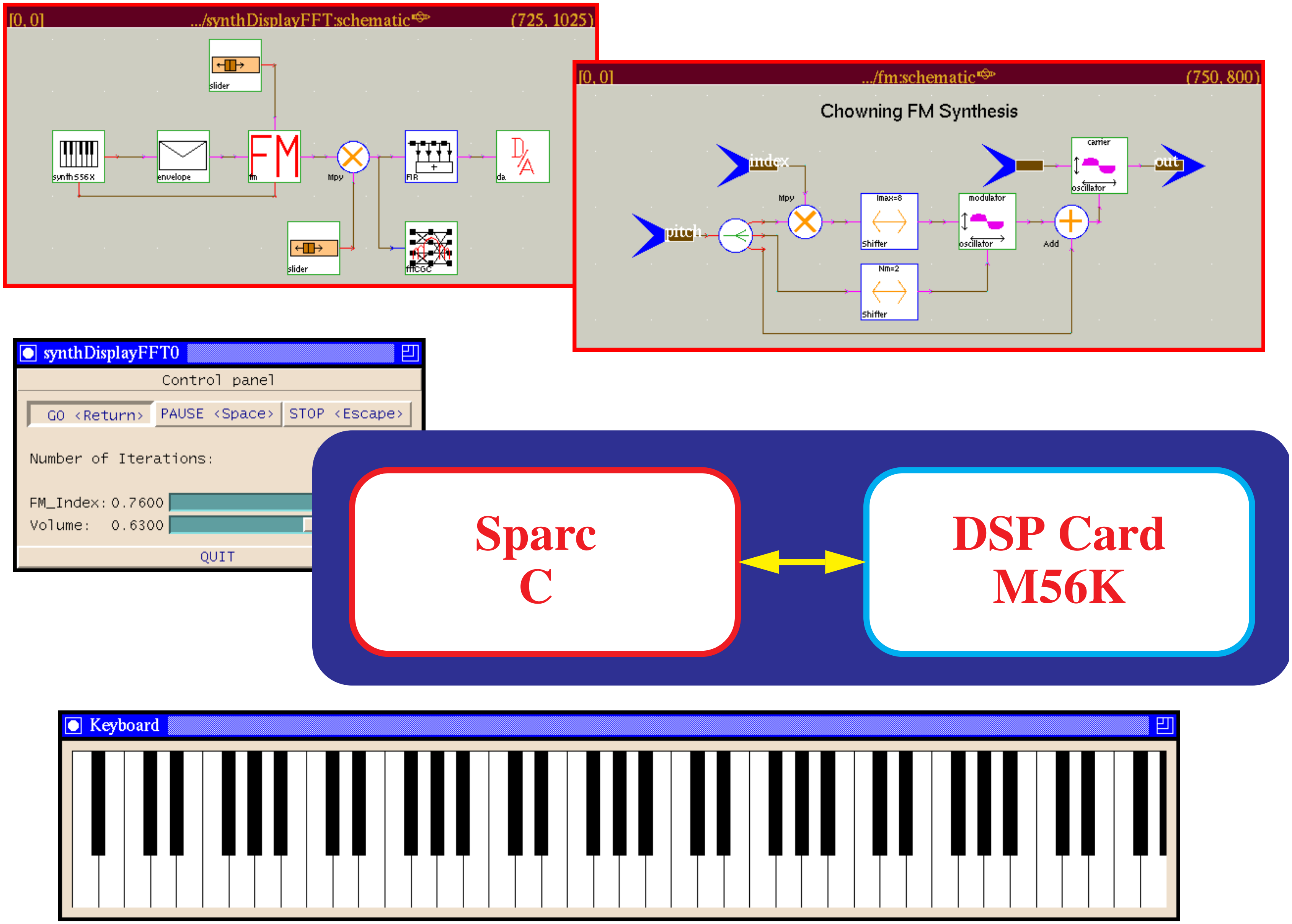
Tomorrow

- Compiled simulation.
- More abstract modeling.
- Cycle-based simulation.



The image above shows a Ptolemy simulation of a multiprocessor system where the software is synthesized (including partitioning) from a block diagram.

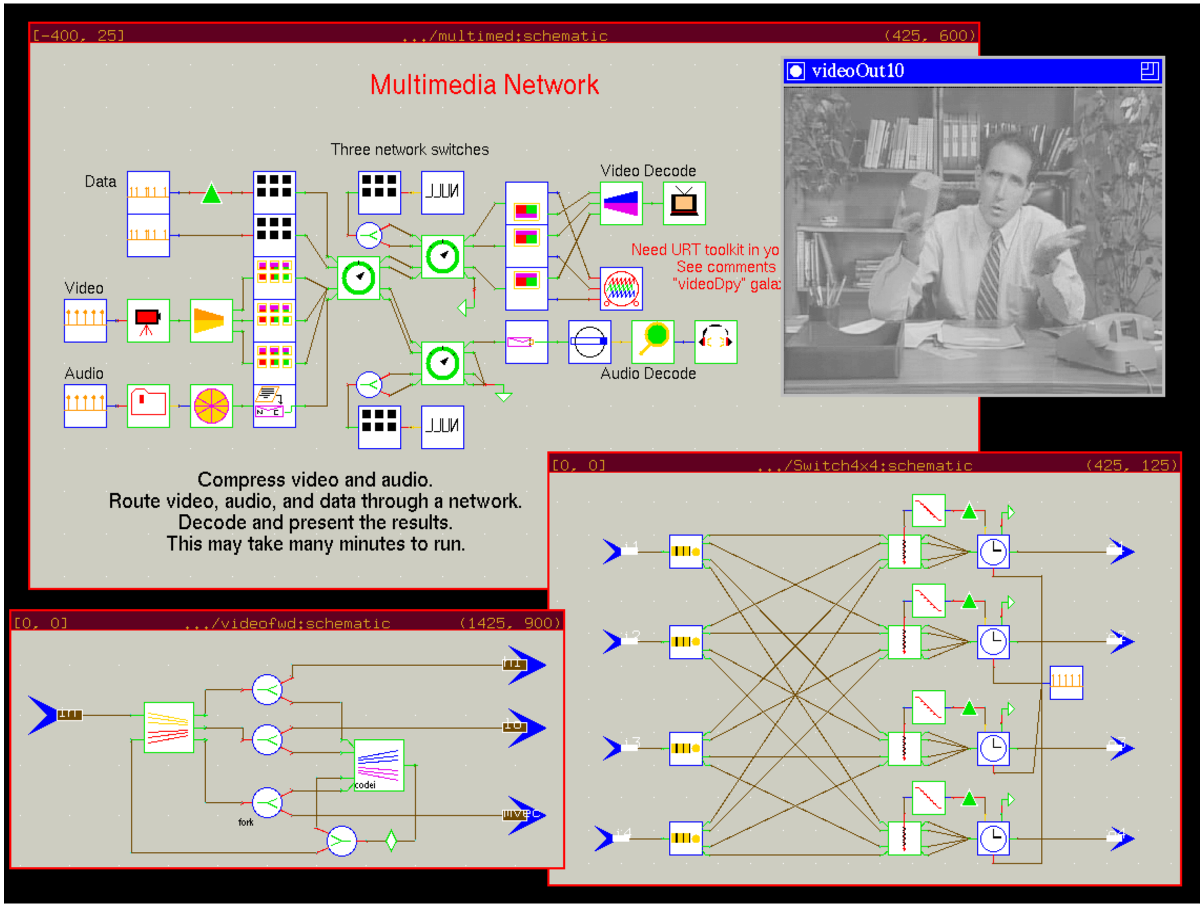
Heterogeneous Real-Time Prototyping



Heterogeneous System-Level Design

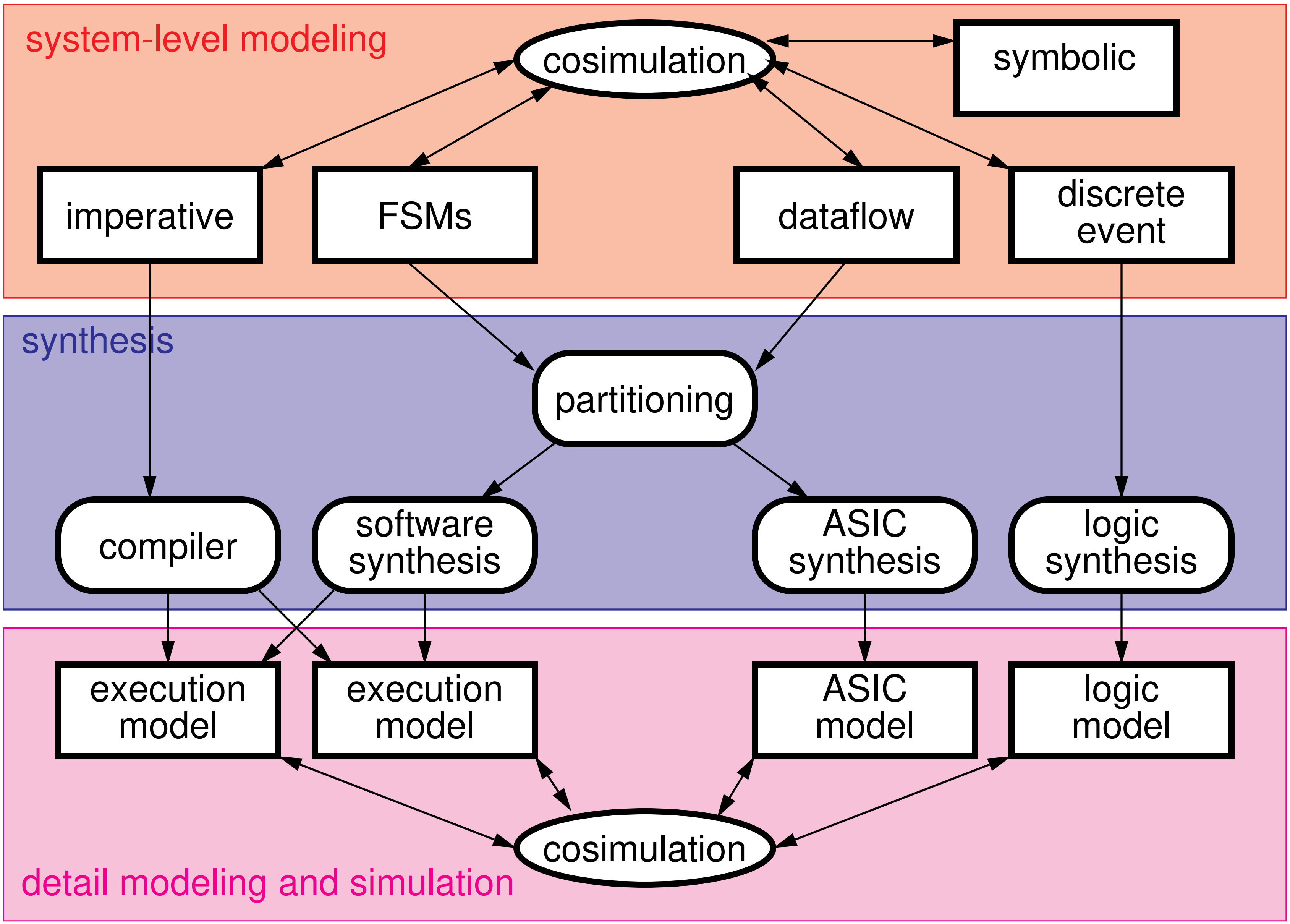
Ptolemy Simulation

- ATM network with three 4x4 switches
- Detailed model of each switch with queueing and routing protocols.
- Dummy traffic (Poisson arrivals) to create congestion.
- Test traffic (video and audio) to measure subjective performance.



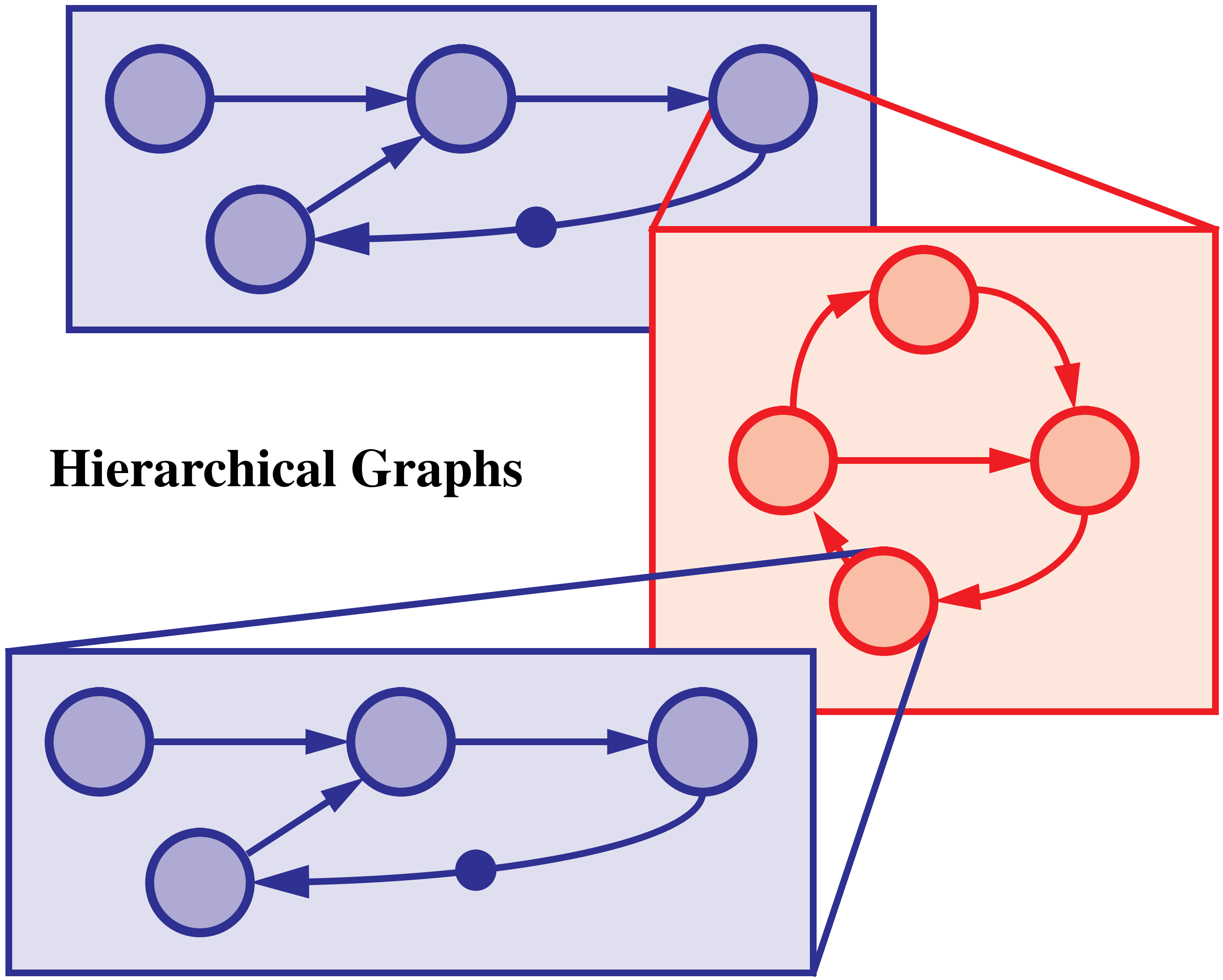
Multiple models of computation may be used in the same system. Here, dataflow is used for signal processing, while a timed discrete-event system models a communication network.

Heterogeneity in System-Level Design



A Flexible Abstract Syntax

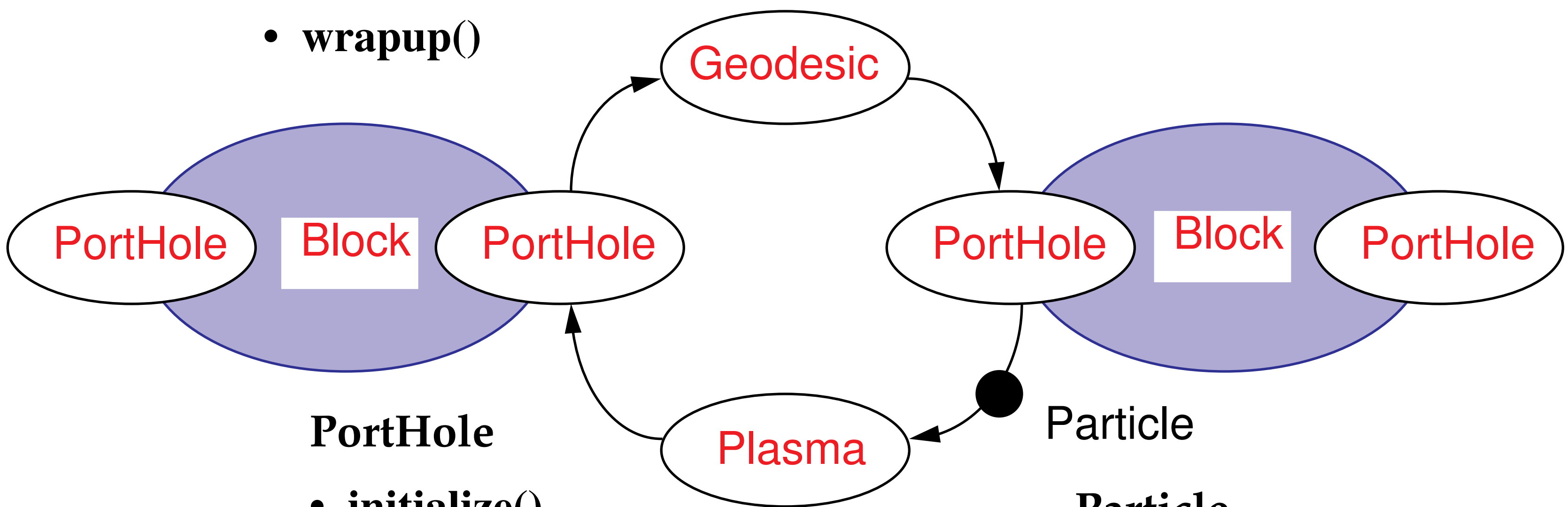
Hierarchical Graphs



Ptolemy C++ Base Classes Support this Abstract Syntax

Block

- **initialize()**
- **run()**
- **wrapup()**



PortHole

- **initialize()**
- **receiveData()**
- **sendData()**
- **type()**

Particle

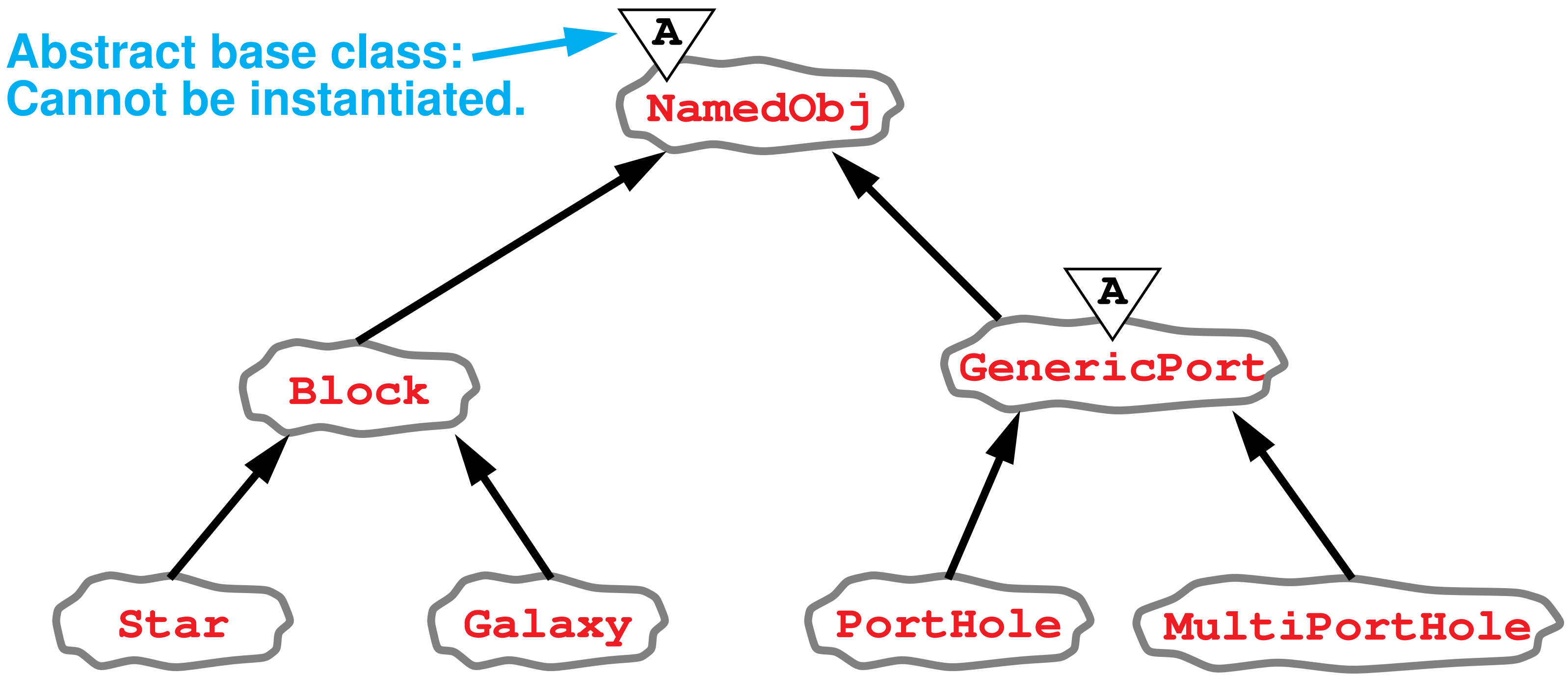
- **type()**
- **print()**
- **initialize()**

Object-Oriented Programming

- inheritance
- data abstraction
- polymorphism

The idea is to use a heterogenous software environment to develop heterogeneous designs. The interaction between different modules in the software environment is managed through object-oriented principles.

Some Kernel Classes (Booch Notation)



C++ class:

- Members & Methods
- Public, Protected, Private

Inheritance: A derived class has all the properties of the parent, plus more.

Data abstraction: Hiding the irrelevant and amplifying the essential.

Polymorphism: Objects with identical interface have different implementations.

Example: NamedObject

```
class NamedObj {
public:
    NamedObj ();
    NamedObj (const char* n,Block* p,const char* d);

    const char* name() const;
    const char* descriptor() const;
    Block* parent() const;

    void setParent (Block* my_parent);
    void setName (const char* my_name);

    virtual const char* className() const;
    virtual int isA(const char* cname) const;

    virtual void initialize() = 0;
private:
    const char* nm;
    Block* prnt;
    const char* myDescriptor;
}
```

Example: NamedObject

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class NamedObj {
public:
    NamedObj ();
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    const char* name() const;
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    virtual int isA(const char* cname) const;

    virtual void initialize() = 0;
private:
    const char* nm;
    Block* prnt;
    const char* myDescriptor;
}
```

Two possible constructors

Methods to access private members

Methods to set private members

Methods to get class information

Private members

Example: NamedObject

```
class NamedObj {
public:
    NamedObj ();
    NamedObj (const char* n,Block* p,const char* d);
```

The return value cannot be modified. The string will not be modified

```
    const char* name() const;
    const char* descriptor() const;
    Block* parent() const;

    void setParent (Block* my_parent);
    void setName (const char* my_name);

    virtual const char* className() const;
    virtual int isA(const char* cname) const;
```

Calling a virtual method gives the version in the derived class

```
    virtual void initialize() = 0;
private:
```

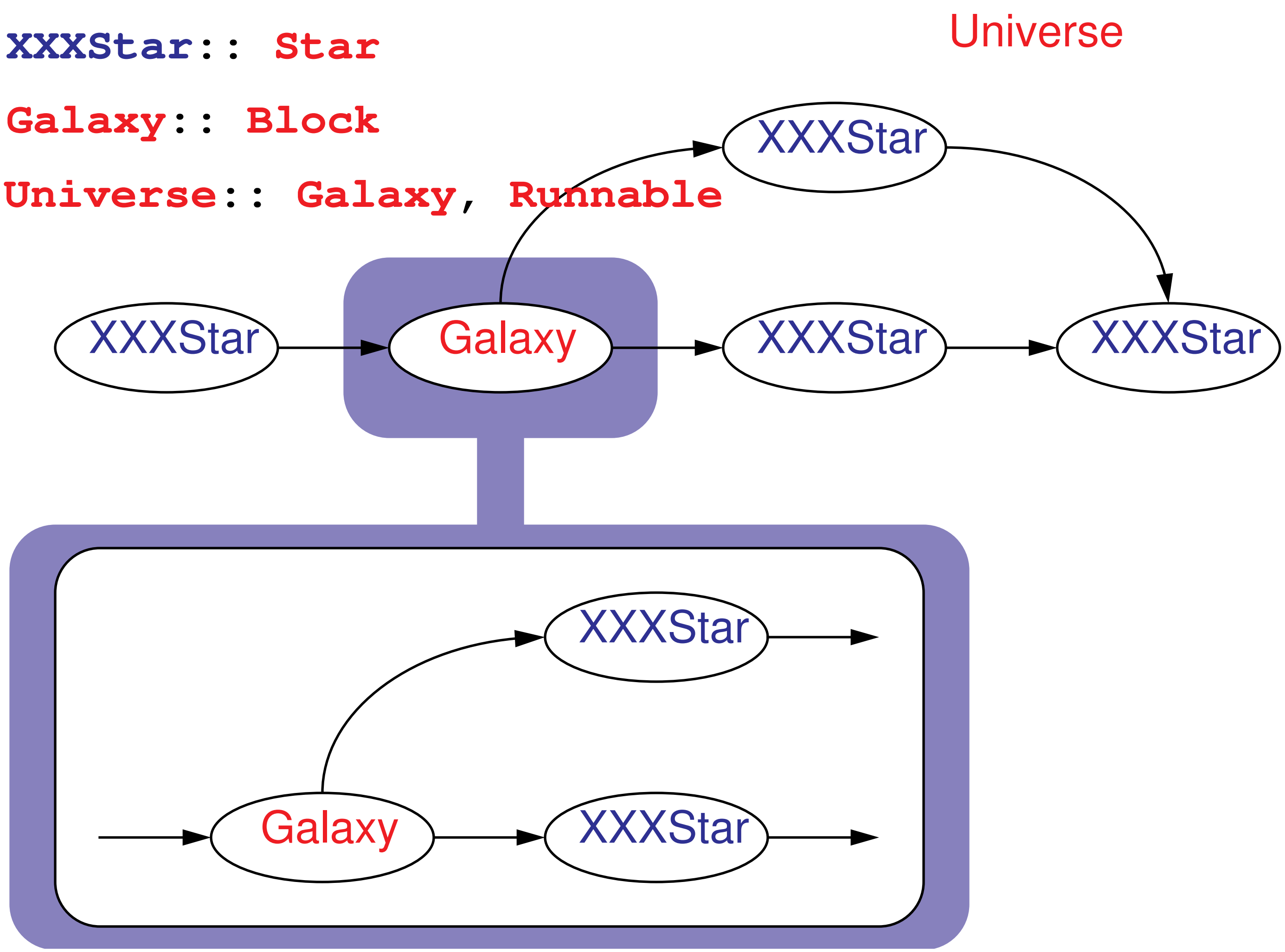
Pure virtual method

```
    const char* nm;
    Block* prnt;
    const char* myDescriptor;
}
```

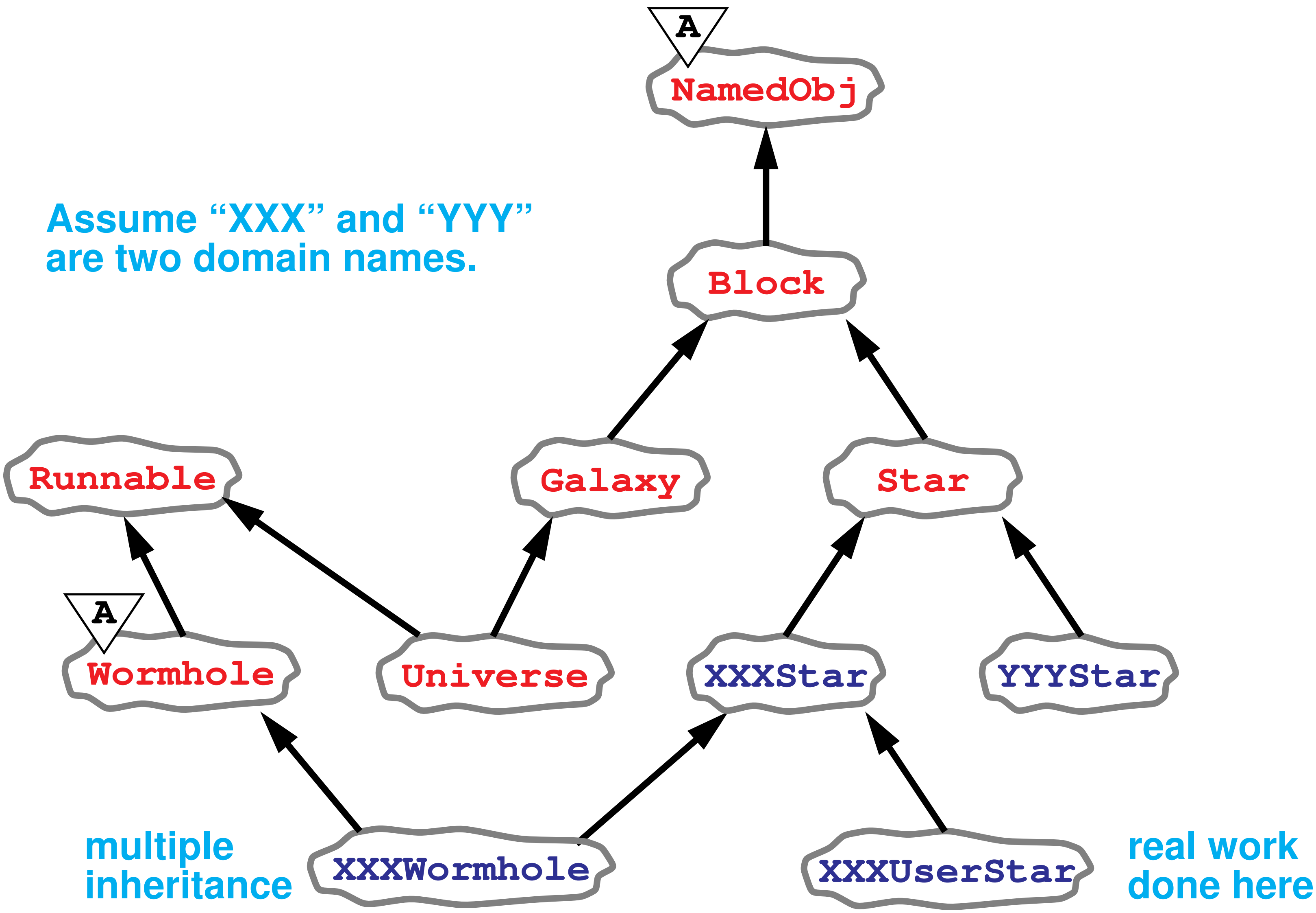
Hierarchical Abstraction

Examples of Derived Classes

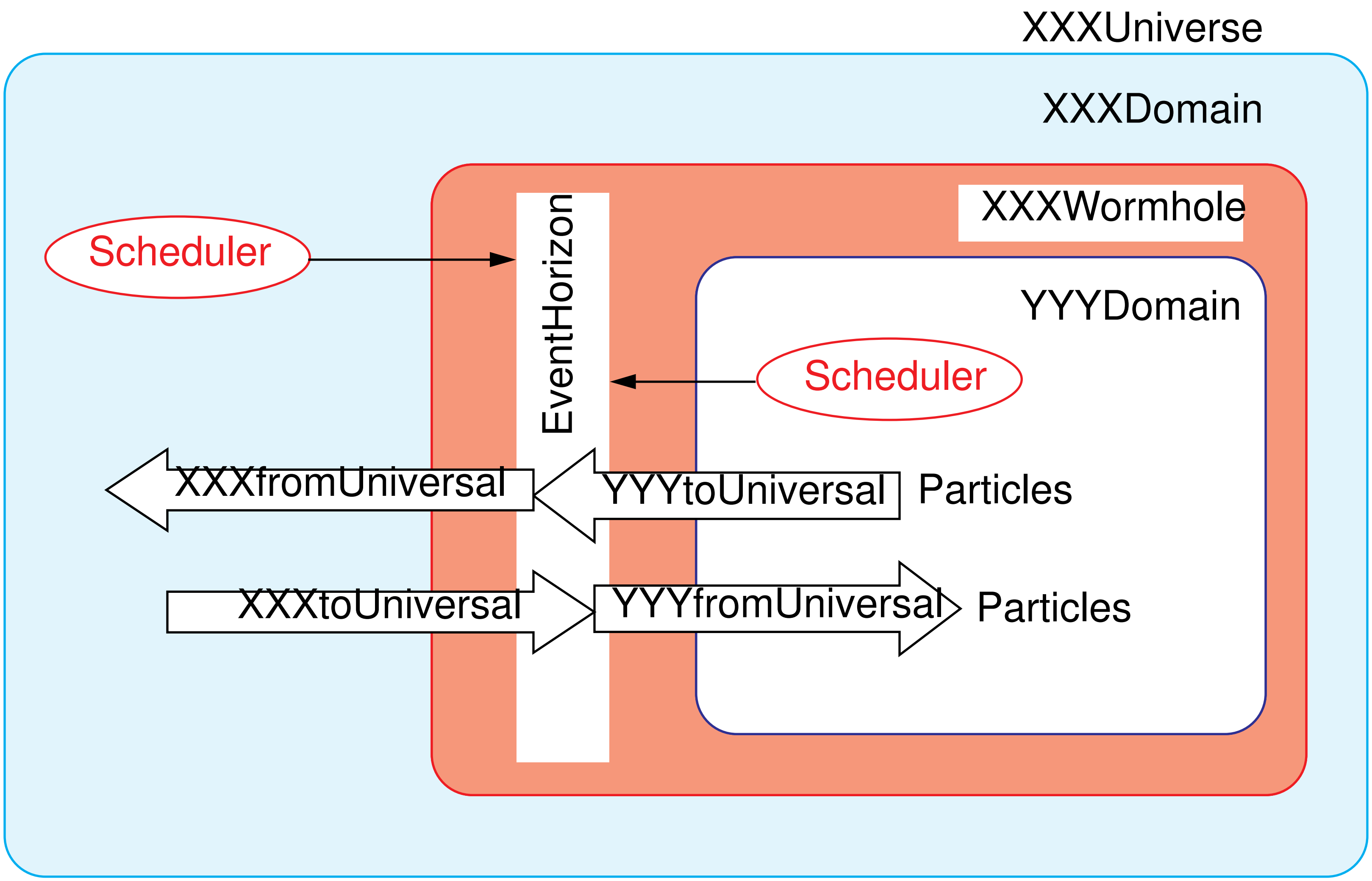
- `class Star:: Block`
- `class XXXStar:: Star`
- `class Galaxy:: Block`
- `class Universe:: Galaxy, Runnable`



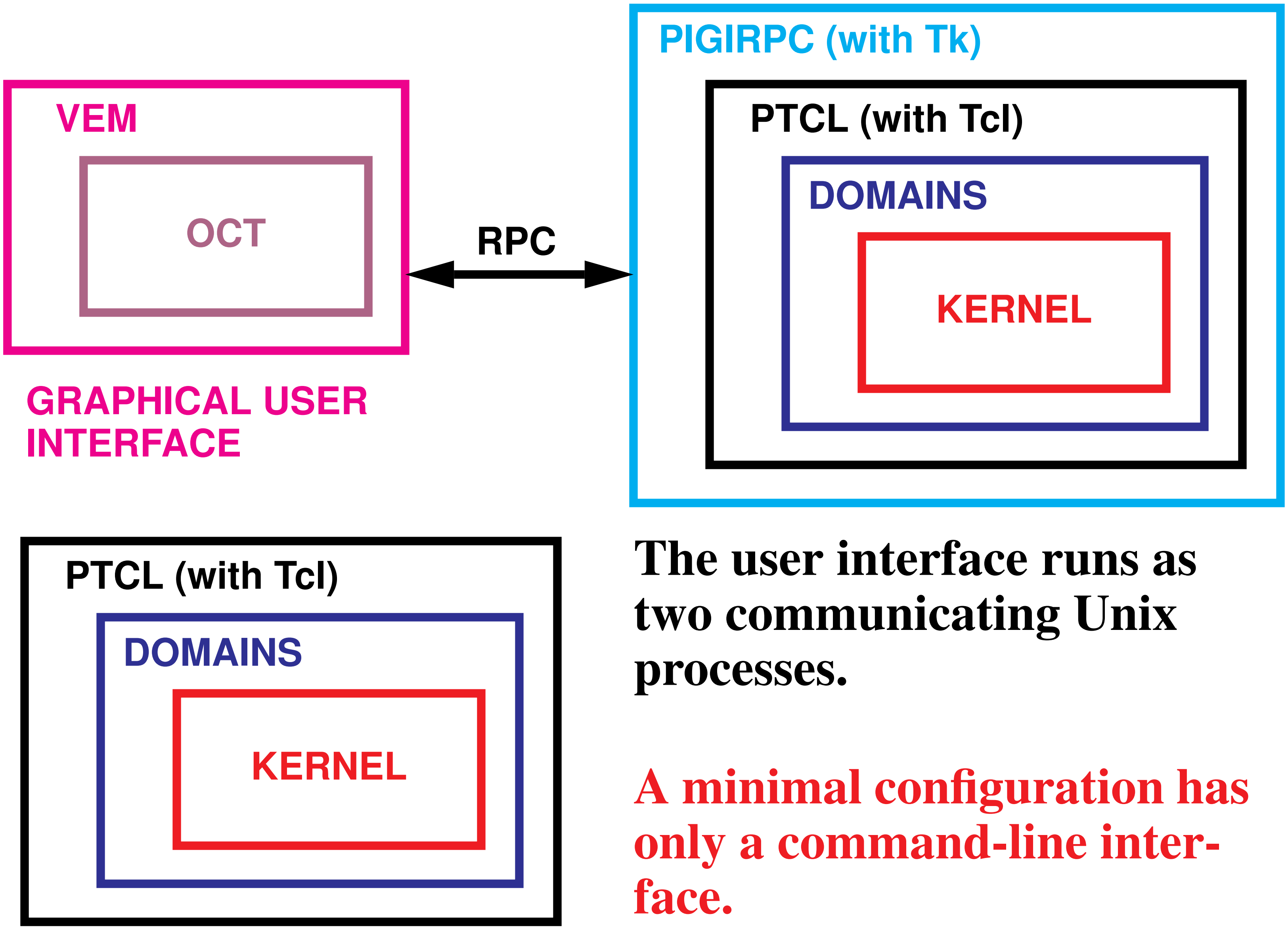
Domain Classes Derived from Kernel Classes



Interaction Across Models of Computation



Overall Software Organization



The user interface runs as two communicating Unix processes.

A minimal configuration has only a command-line interface.

Standard forms of the Ptolemy Executables

pigi

- All domains and targets plus the GUI.

ptrim

- SDF, BDF, DDF, DE, CGC and HOF domains plus GUI.

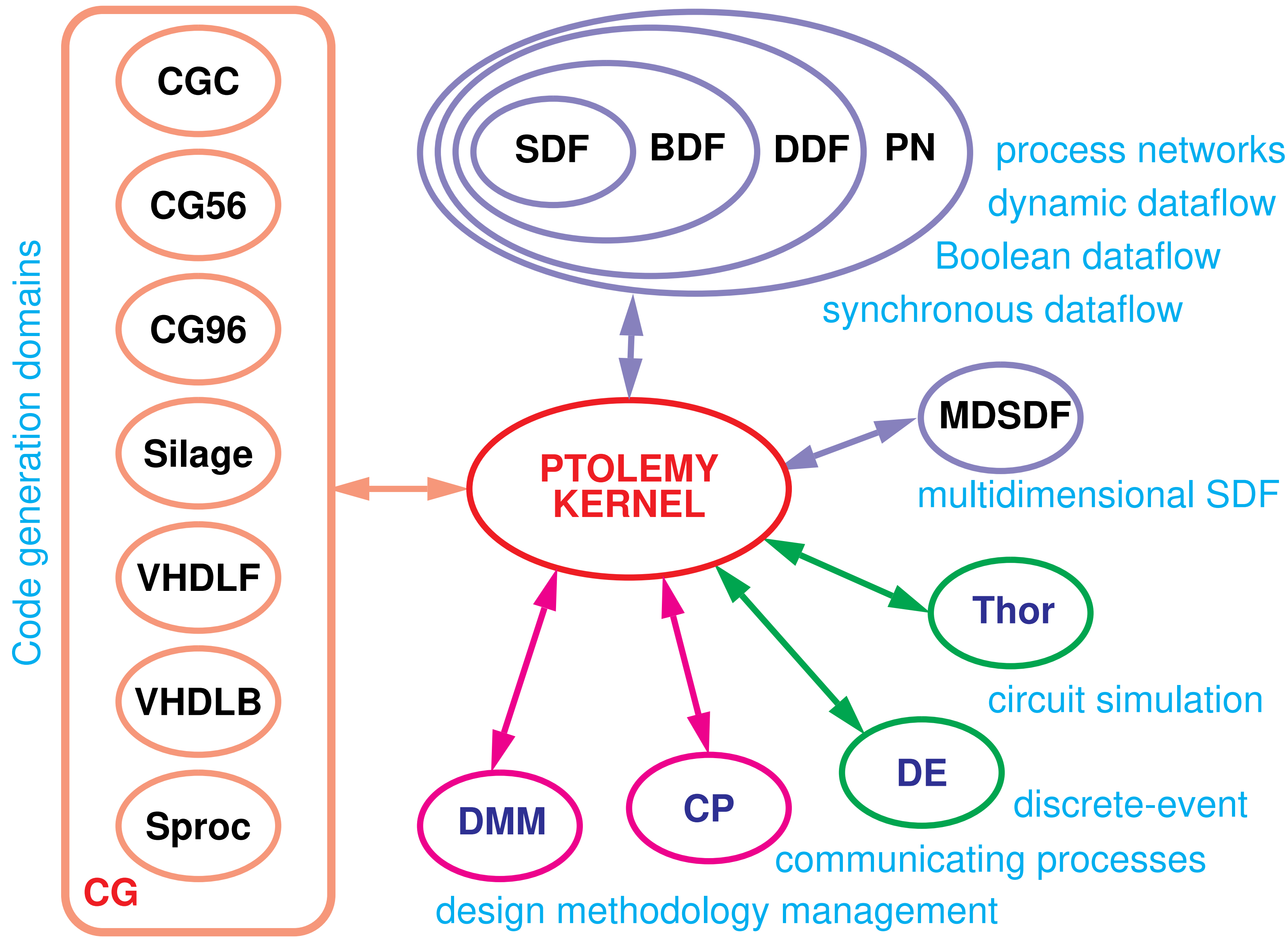
ptiny

- SDF and DE domains plus GUI.

ptcl

- All domains, no GUI.

Domains in Ptolemy



Ptolemy is an Extensible Open Architecture

Extensions that are possible:

- applications
- a library of galaxies
- application builders (using ptcl)
- a library of custom stars
- customized user interfaces (using Tcl/Tk)
- simulation managers (Targets)
- domains
- foreign simulators and/or synthesis tools

File Organization

$PTOLEMY

bin	platform-independent executables
bin.$ARCH	platform-dependent executables
demo	top-level demo palette
doc	documentation (in PostScript)
lib	platform-independent run-time libraries
lib.$ARCH	platform-dependent libraries
mk	shared portions of makefiles
obj.$ARCH	object files (upon recompilation)
octtools	a subset of the Berkeley octtools
src	root of the source tree (required!)
tcltk	Tcl and Tk

To run ptolemy, set the environment variable PTOLEMY to the root directory of the installation and put $PTOLEMY/bin in your path.

The preferred installation location is /users/ptolemy.

The Source Tree

$PTOLEMY/src

compat	header files for odd configurations
domains	the code for each of the domains
filters	outside filter design programs
kernel	the Ptolemy kernel
libgantt	the Gantt chart display tool
octtools	our subset of the oct tools
pigiExample	example to make a custom pigi
pigiRpc	source for pigiRpc program
pigilib	source for most of pigi
ptcl	source for ptcl
ptklib	shared Tcl/Tk code
ptlang	the preprocessor for star writing
tcltk	source for Tcl and Tk
thread	code used by the CP domain
utils	utilities
xgraph	the pxgraph program

The Domains Directory

$PTOLEMY/src/domains

bdf	Boolean dataflow domain
cg	base classes for code generation
cg56	Motorola DSP56000
cg96	Motorola DSP96000
cgc	code generation in C
cp	communicating processes (sun)
ddf	dynamic dataflow
de	discrete-event
mq	message queue
sdf	synchronous dataflow
silage	Silage code generation
sproc	Sproc DSP (obsolete)
thor	hardware simulation
vhdlb	behavioral modeling in VHDL
vhdlf	functional modeling in VHDL
xxx	demonstration new domains

Within Each Domain Directory

$PTOLEMY/src/domains/xxx

demo	applications in the domain
icons	the icons used by pigi
kernel	core code defining the domain
stars	stars in the domain
targets	(optional) additional targets

The stars in a domain are an excellent resource for learning about how to write custom stars for the domain.

READ THE SOURCE

Documentation — User-Oriented

The Almagest

Volume 1
User's Manual
pigi
ptcl
domains
vem
pxgraph
installation

Volume 2
Star Atlas
detailed documentation
of all stars
(not up-to-date)

Documentation — Programmer-Oriented

Volume 3
Programmer's Manual
software organization
writing stars
infrastructure
data types
Tcl/Tk
domains
code generation

Volume 4
Kernel Manual
detailed documentation
of all C++ classes
defined in the kernel.
Essential for defining
Targets and Domains.