Experiment Management Support for Performance Tuning

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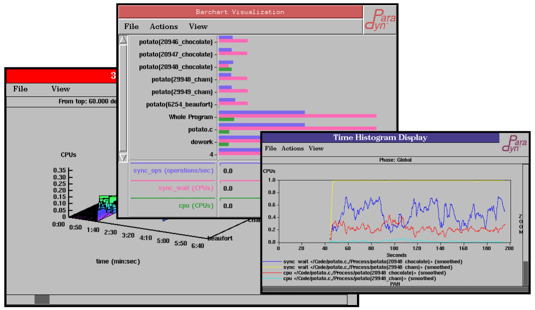
Publications

- **"The Paradyn Parallel Performance Measurement Tools," B.Miller, M. Callaghan, J. Cargille, J. Hollingsworth, R. Bruce Irvin, K.Karavanic, K.Kunchithapadam, and T.Newhall. IEEE Computer, November 1995.**
- **"Integrated Visualization of Parallel Program Performance Data," Karen L. Karavanic, J. Myllymaki, M. Livny, B. Miller. Parallel Computing 23:181-198, 1997.**
- **"Experiment Management Support for Performance Tuning," K. Karavanic and B. Miller. SC'97.**
- **"Improving Online Performance Diagnosis by the Use of Historical Performance Data," K. Karavanic and B. Miller. Submitted.**

What is a Parallel Performance Tool?

- **Goal**
  - Provide Meaningful Feedback about Application Behavior
- **Insert Instrumentation**
  - Hardware vs. Software
  - Profiling vs. Tracing
- **Analyze Application Performance**
  - Descriptive Feedback (visualization)
  - Prescriptive Feedback

What is a Parallel Performance Tool?



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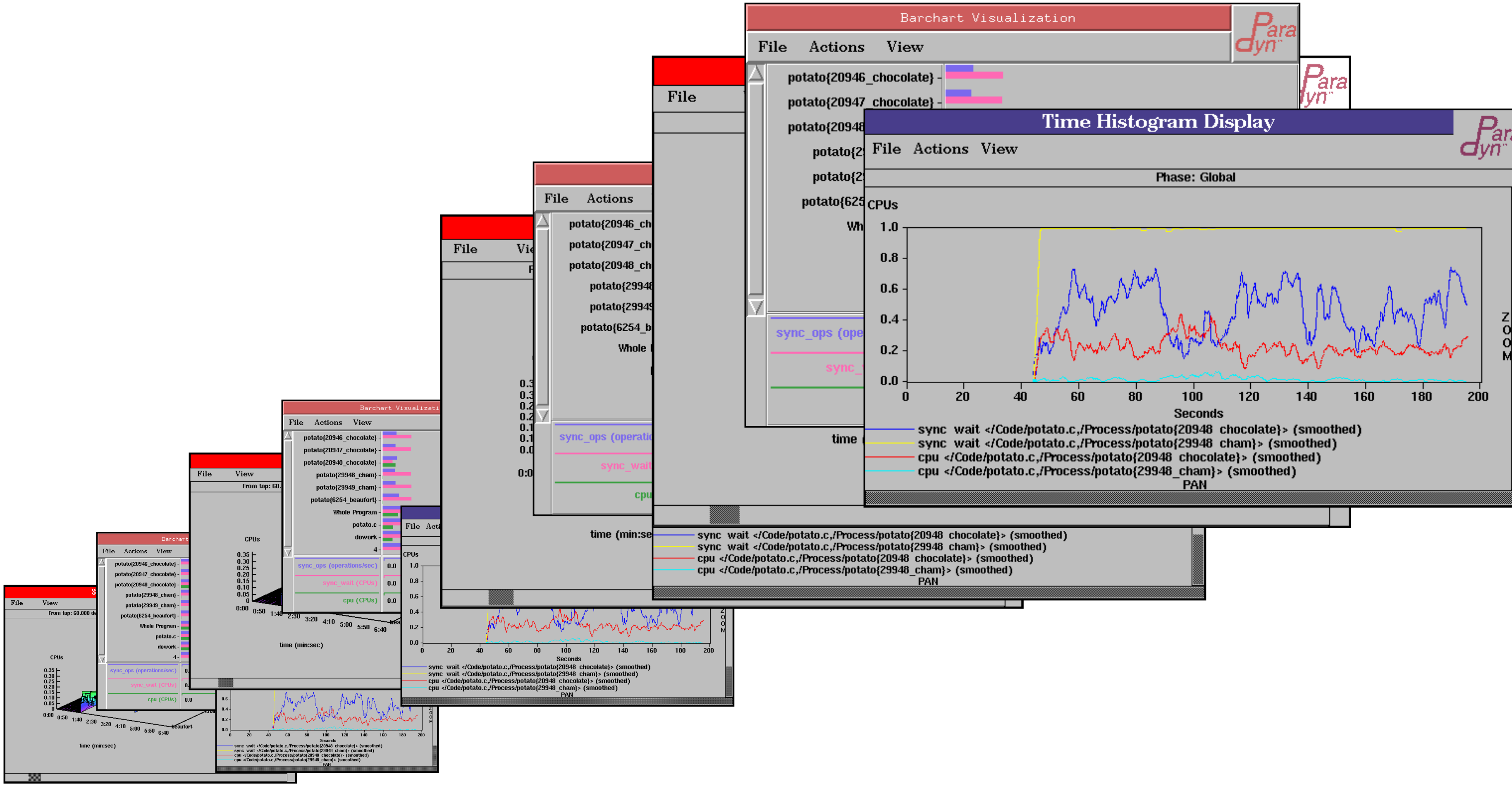

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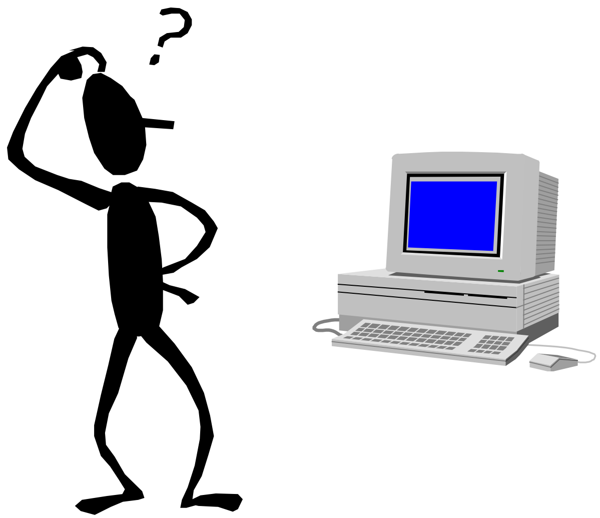


- **“What is the scaling behavior of my code?”**
- **“How do these results compare to other platforms?”**
- **“Did performance of `foo` improve when we compiled with -O3? By how much? ”**
- **“Are the performance requirements being met?”**
- **“What’s the max I/O wait time we’ve seen for runs on more than 16 nodes?”**
- **“How accurate was my predictive model?”**

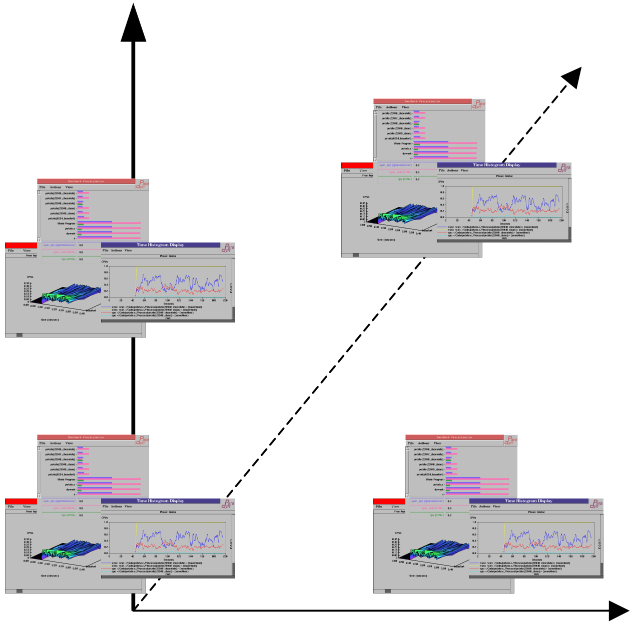
What is a Parallel Performance Tool?

- **Current Performance Tools: Performance of a single program run**
- **The Actual Evaluation Tasks: Inherently multi-execution**
  - Performance Tuning
  - Software Evolution
  - Porting to new platforms
  - Different Data Sets
  - Benchmarking
  - Regression Testing
  - Model and Simulation Validation
  - Dynamic runtime environments

Our Solution: Experiment Management

- **Performance Tuning as Scientific Experimentation:**
  - An experiment includes one or more instrumented program runs
  - Data: Structural, Performance, Index
  - Automation
- **Name, store, analyze, visualize data from many runs**
- **Performance Data is heterogeneous**

The Multi-Dimensional Experiment Space



- Input data set
- Code version
- Underlying hardware (Processors, Interconnect, Memory)
- Underlying software (libraries)
- Language
- Compiler
- Optimization level

Our Solution: Experiment Management

- **The Program Space**
  - Each program execution is a point
  - Dimensions: platform, version, input data, language, etc.
  - Data: structural, performance, metadata
- **Operations**
  - Automated analysis of points, vectors, planes
    - Simple Queries
    - Comparison Operations
  - Schema Evolution

Talk Outline

Motivation

Representing and Comparing Structural Data

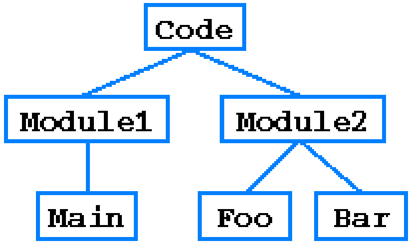
Representing and Comparing Performance Data

Performance Diagnosis Using Multi-Execution Data

Future Work and Conclusions

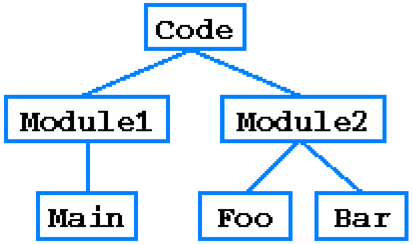
Representing an Execution

- A *resource* is a representation of a logical or physical component of a program execution -- Module1, Main, Process3, node24



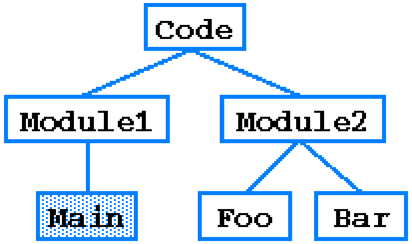
Representing an Execution

- A *resource* is a representation of a logical or physical component of a program execution -- Module1, Main, Process3, node24
- A *resource hierarchy* R is a tree of the form R = (r, T)



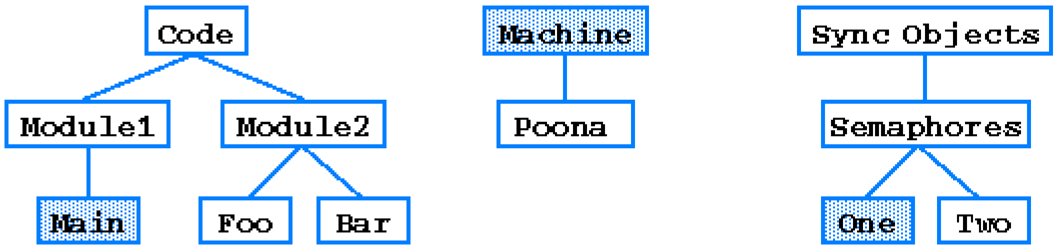
Representing an Execution

- A *resource* is a representation of a logical or physical component of a program execution -- Module1, Main, Process3, node24
- A *resource hierarchy* R is a tree: R = (r, T)
- A *resource name* is formed by concatenating the labels along the unique path within the resource hierarchy from the root to the node representing the resource: /Code/Module1/Main



Representing an Execution (cont'd)

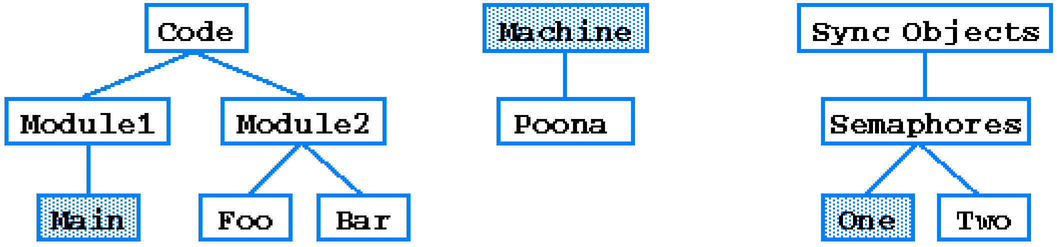
- **A Program Event is a representation of a program run or execution. It is a forest: E = {R0, R1, … Rn}, n>=0**



Representing an Execution (cont'd)

- **A Program Event is a representation of a program run or execution. It is a forest: E = {R0, R1, … Rn}, n>=0**
- **A focus F is formed by selecting one resource node from each of the resource hierarchies R:**

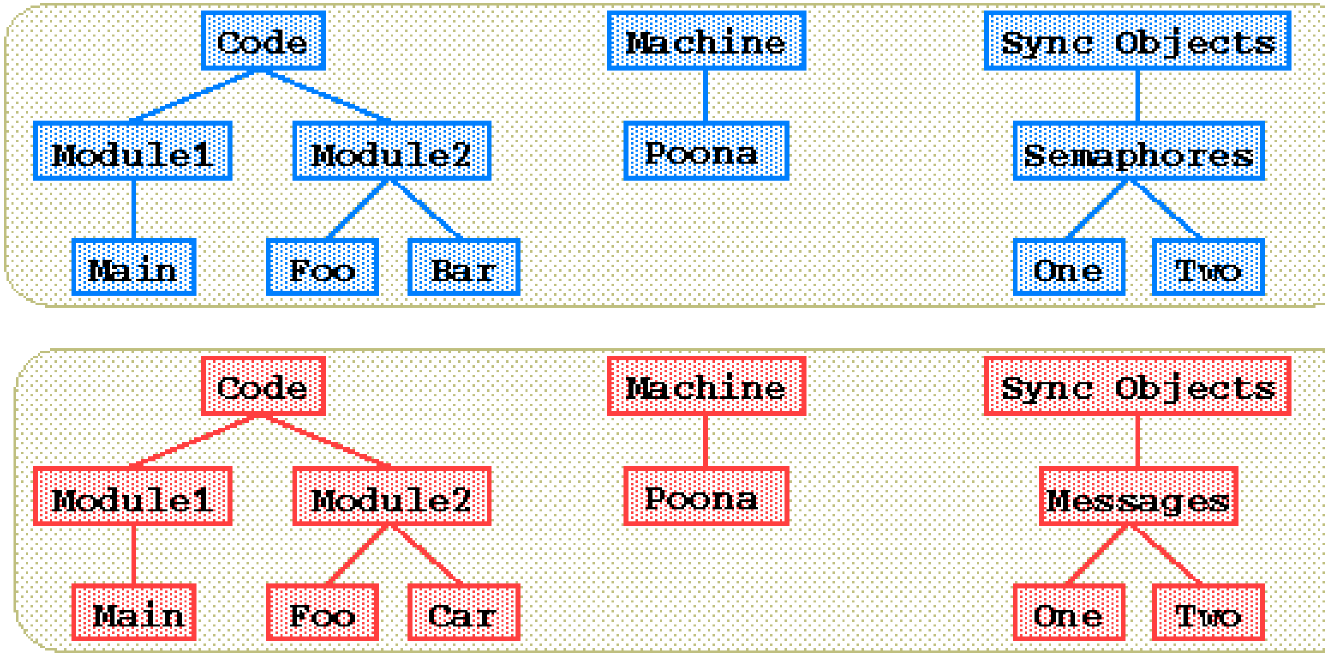
  </Code/Module1/Main,/Machine,/SyncObjects/Semaphores/One>



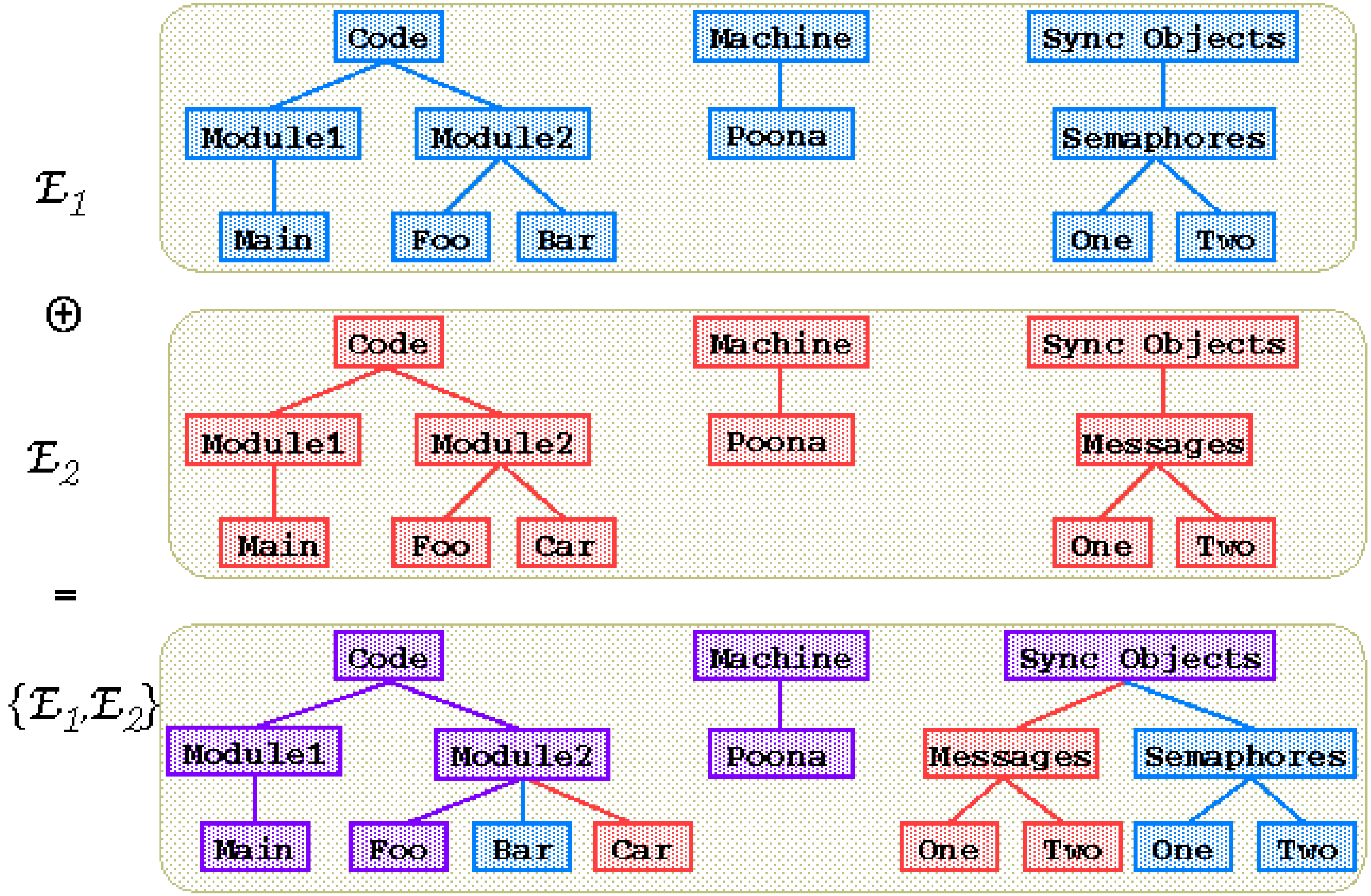
Comparing Program Events

- **Goals:**
  - What has changed in the code? In the run-time environment?
  - How different are the two executions?
- **The Structural Difference Operator**
  - A top-down comparison of two or more Program Events

Comparison Operators: the Structural Difference



Comparison Operators: The Structural Difference



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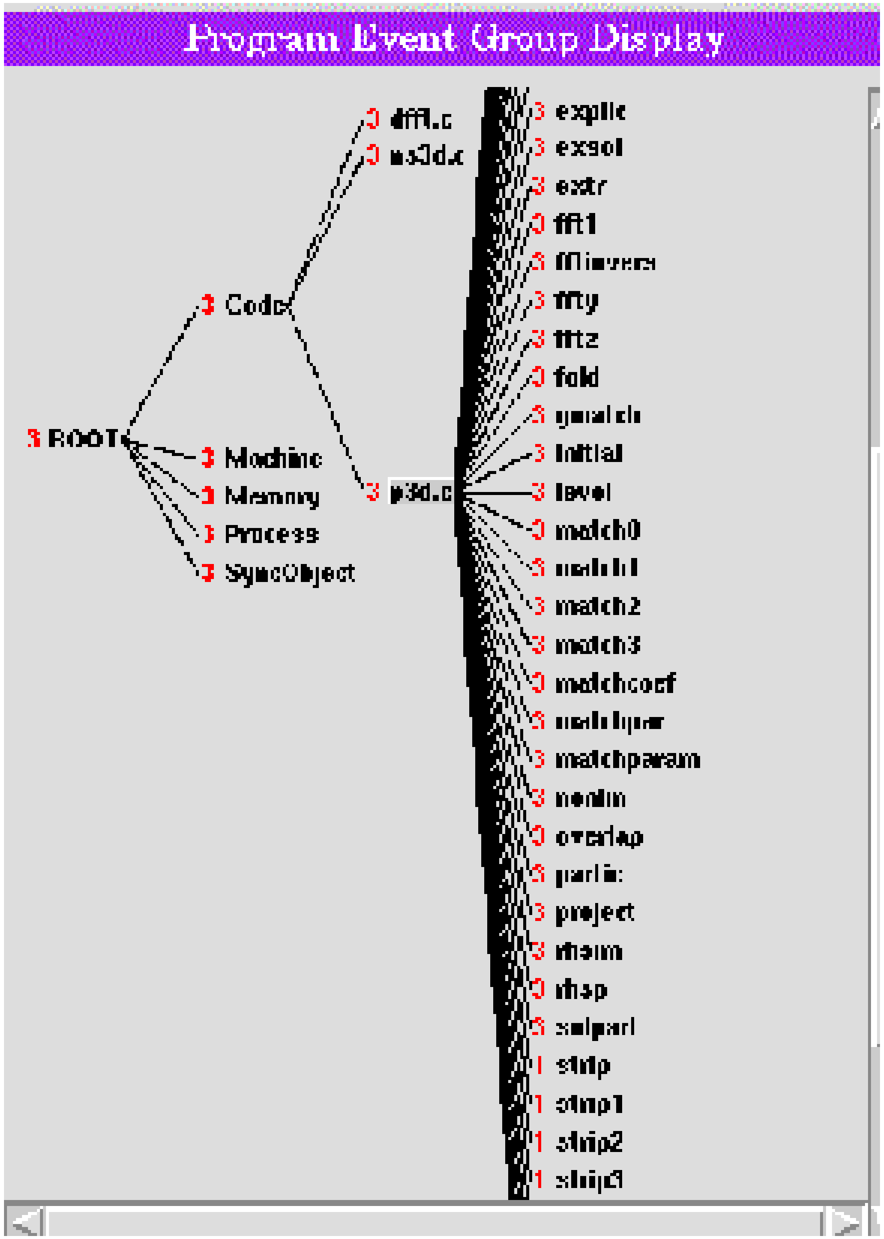
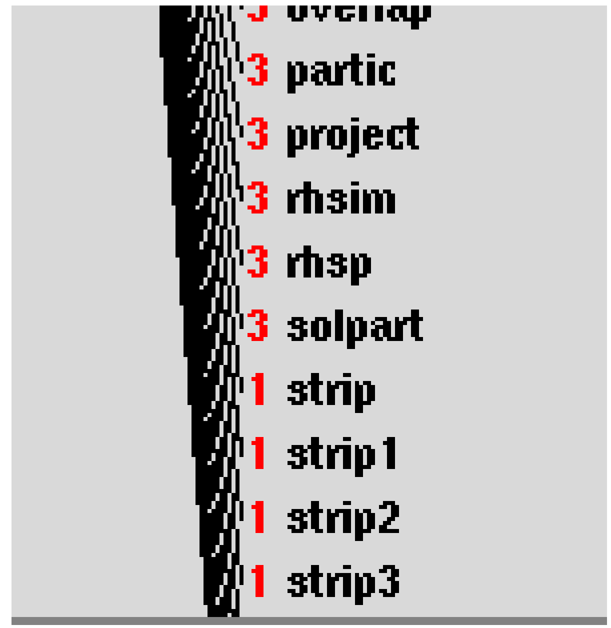
Case Study: Changing Communication Libraries

- **Parallel message-passing FFT code versions**
  - MPI
  - PVM
- **Goal: provide feedback on the structural changes in the application code to the scientist**
- **Method: construct Program Events using Paradyn data and apply Structural Difference Operator**
- **Result: we focus attention directly to the structural changes which resulted from changing libraries**


Program Event Group Display
ROOT
Code
Machine
Memory
Process
SyncObject
p3d.c
explic
exsol
extr
fft1
ffty
fftz
fold
initial
level
match0
match1
match2
match3
matchparam
overlap
partic
project
rhsim
rhsp
solpart
strip
strip1
strip2
strip3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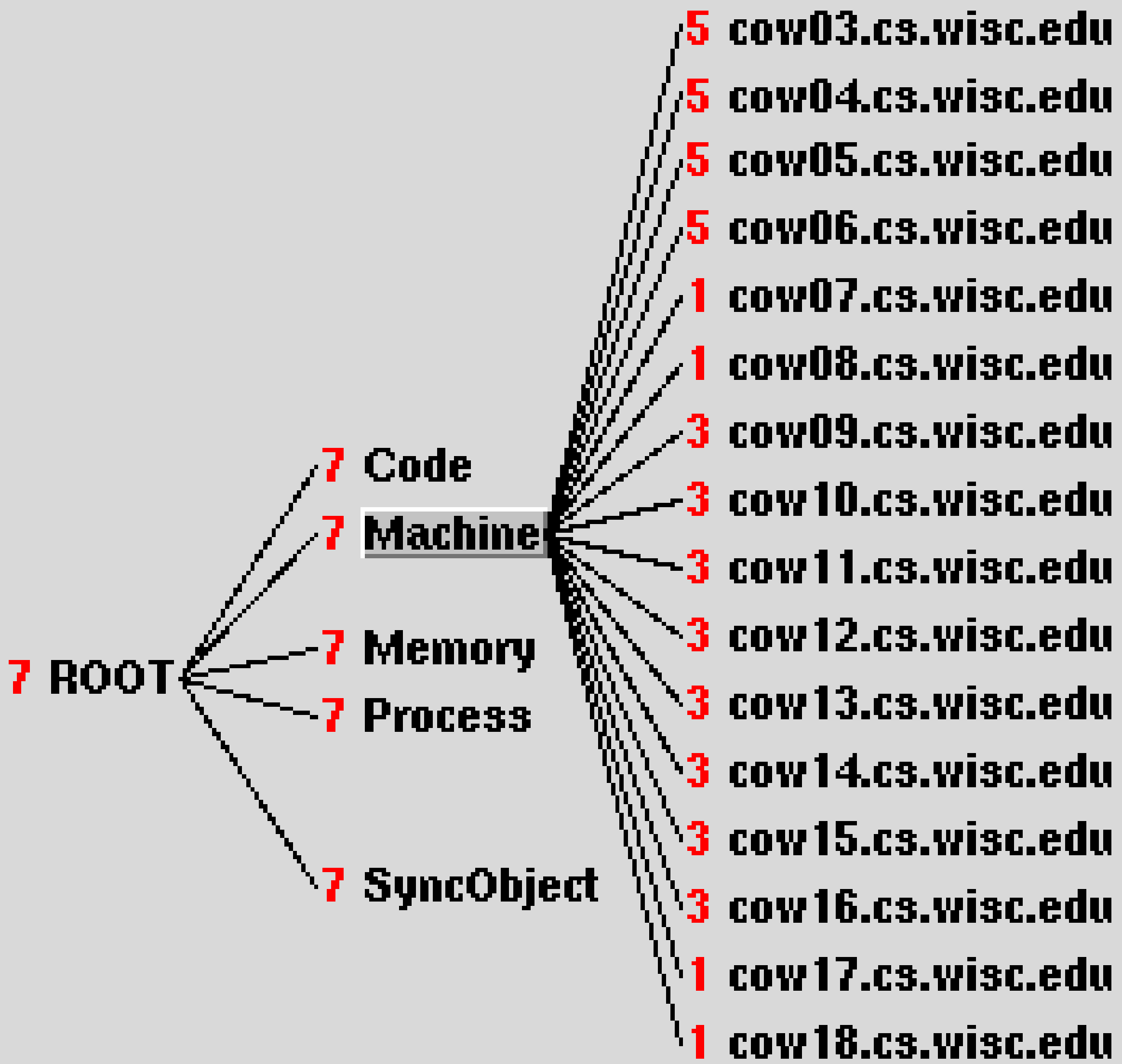
Program Event Group Display



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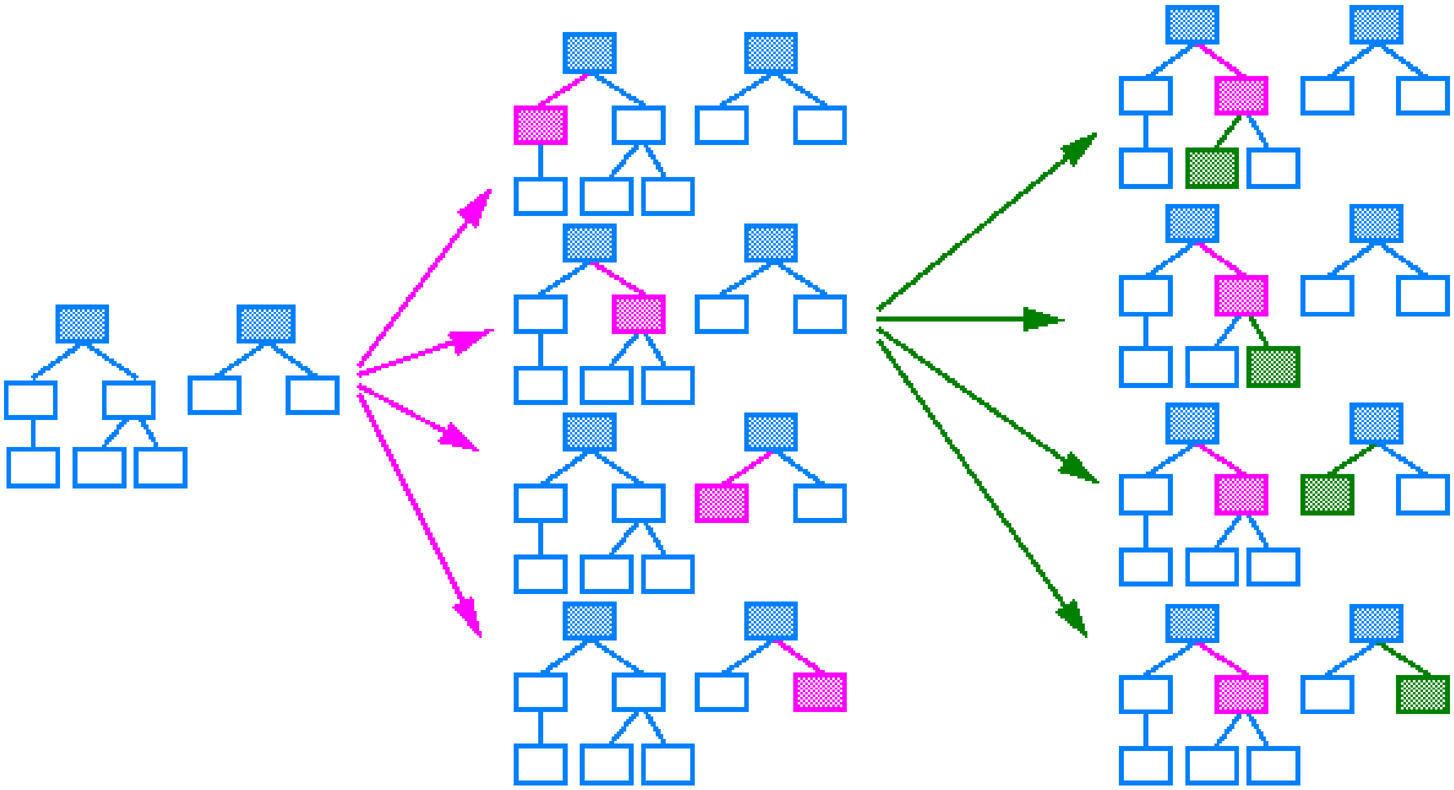
Representing Performance Data

- **We represent each performance result r as P(e, m, f, t):**
  - e: a program execution
  - m: the metric, a measurable execution characteristic
    - CPU time, Synchronization waiting time
  - f: the focus for this performance measure
    - CPU time for focus </Code/Module1/Main, /Machine, /Process>
  - t: the time interval

- **A performance result may be a simple scalar or more complex object: list of values, Paradyn histograms, traces**

Representing Performance Data

Focus provides a partial ordering of the data:



Comparison Operators: The Performance Difference

</Code, /Machine, /SyncObjects>

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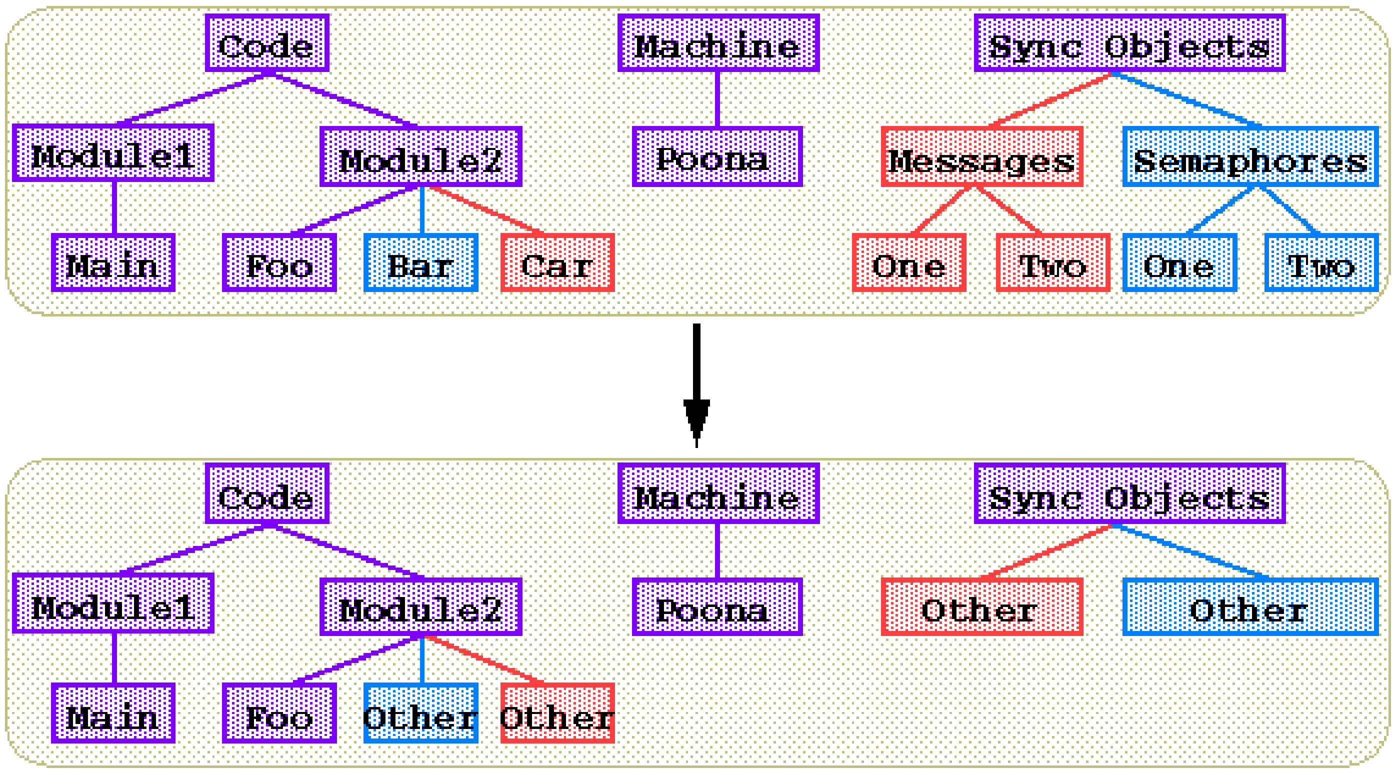
Comparison Operators: The Performance Difference

- Starting point is Program Event Group:



Comparison Operators: The Performance Difference

- Traverse performance results in a top-down manner
- Apply Distance Metric d to each pair of performance results:

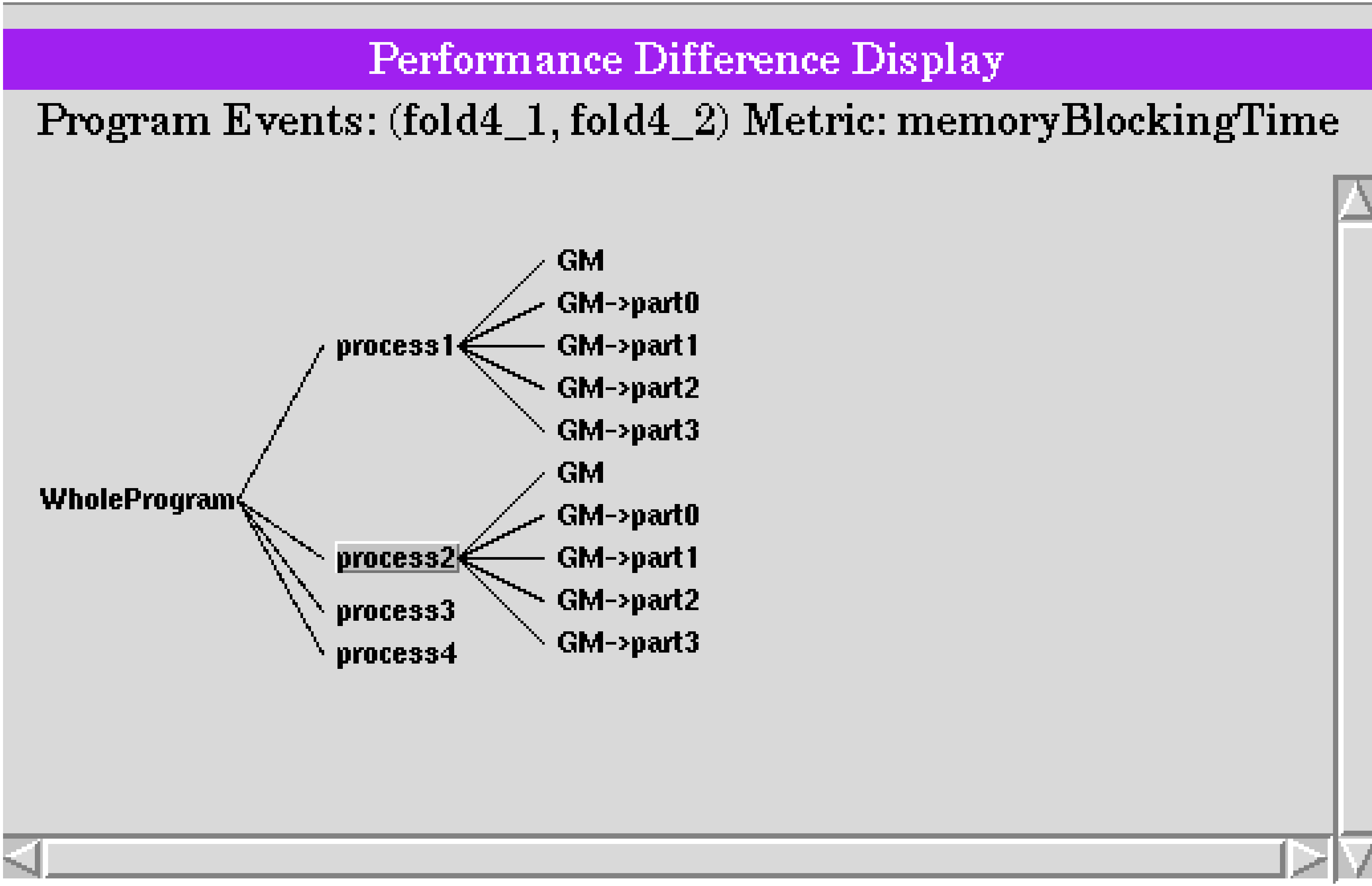
  d = r1 - r2
  d = P(e1, m1, f1, t1) - P(e2, m2, f2, t2)

- If d significantly large, mark different and continue comparison
- Stop when d is insignificant or zero
- Display changes in Performance Difference Display

Case Study: A Performance Tuning Study

- **Original Study**
  - Protein-folding simulation from UW-Madison Chemical Engineering ported to Wisconsin COW
  - Data: Paradyn histograms gathered using Paradyn/Blizzard
  - 13,000 resource nodes, 3-4 person-weeks

- **Our Goal**
  - focus attention to performance changes between versions in tuning study using Performance Difference Operator


Performance Difference Display
Program Events: (fold4_1, fold4_2) Metric: memoryBlockingTime
WholeProgram
process1
GM
GM->part0
GM->part1
GM->part2
GM->part3
process2
GM
GM->part0
GM->part1
GM->part2
GM->part3
process3
process4

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Performance Diagnosis Using Multiple Program Events

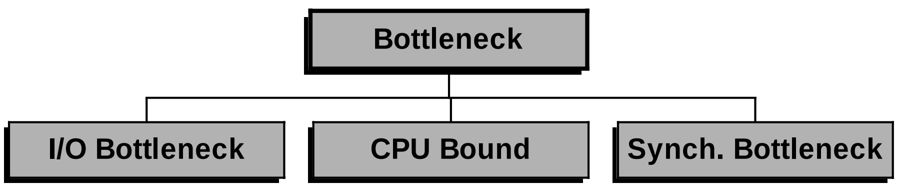
- **Tools for Automated Performance Diagnosis**
  - ATExpert, MPP Apprentice (CRAY)
  - Poirot (Helm, Malony - U of Oregon)
  - Paradyn's Performance Consultant (Hollingsworth, Miller)
- **Collaborative Effort**
  - APART (FZ Juelich, UW-Madison, U of Oregon, etc.)

Performance Diagnosis Using Multiple Program Events

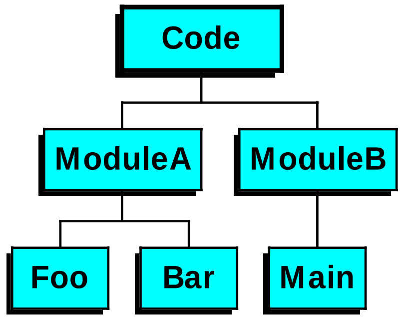
- **Improve Existing Methods -- Performance Consultant**
  - Directing the Search Strategy
  - Data Collection across multiple program runs
- **New Methods**
  - Automated Performance Difference

Paradyn's Performance Consultant (Some Background)

Why Axis



Where Axis



- **Experiment:**
  - Why + Where ? Threshold
- **Search Expansion**
  - Refinement
  - Dynamic Instrumentation
- **Perturbation**
  - information vs uncertainty
- **Application Familiarity**

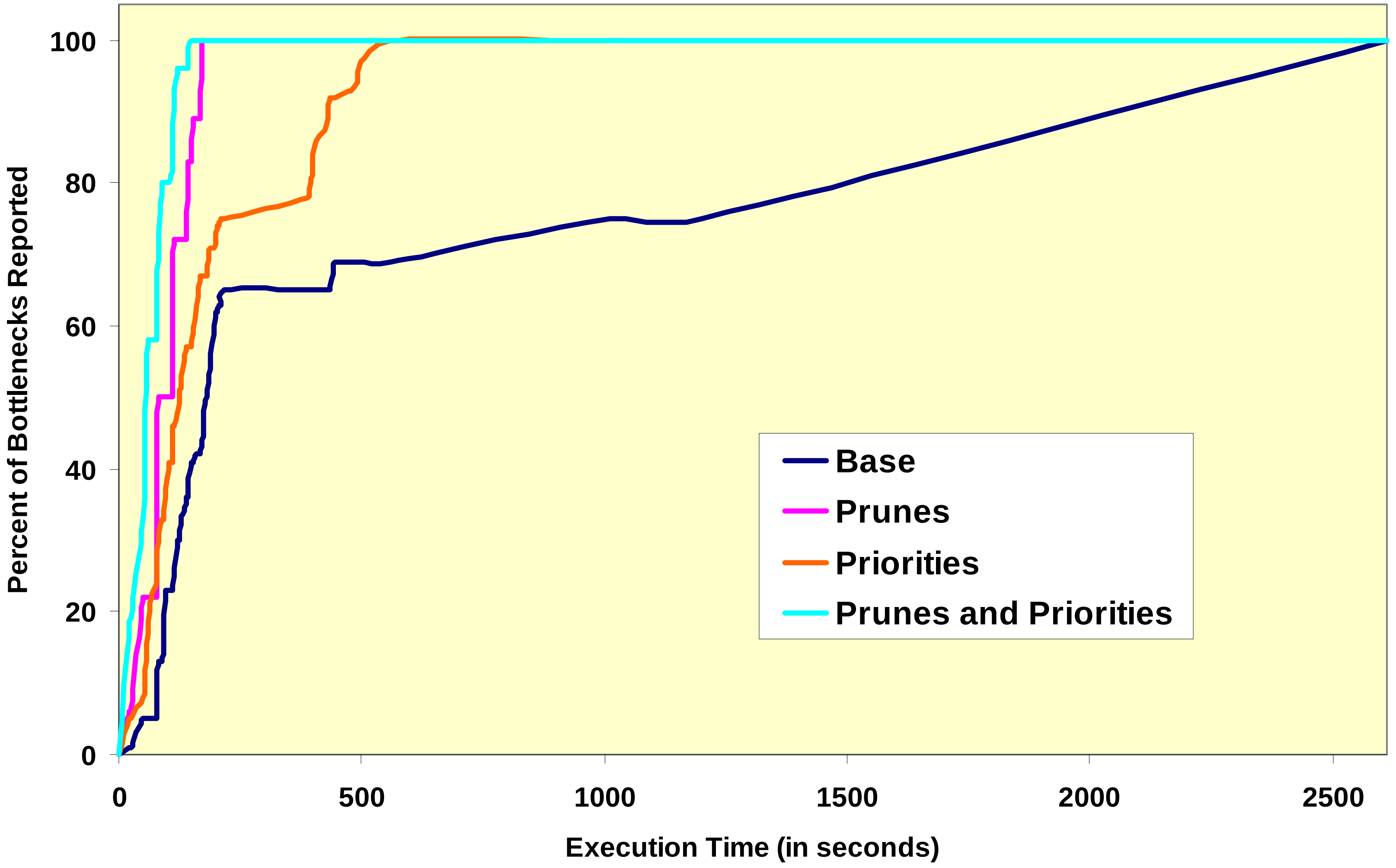
Performance Diagnosis Using Multiple Program Events

- **Goals**
  - Shorten time to find important bottlenecks
  - Decrease unhelpful instrumentation
  - Determine precise location of all significant bottlenecks

Performance Diagnosis Using Multiple Program Events

- **Adding Prior Knowledge to the Performance Consultant**
  - Prunes
    - remove resource hierarchy subtree
    - what to prune?
    - robustness
  - Priorities
    - order the PC search
    - partition hypothesis-focus pairs
  - Thresholds
    - too low --> high cost
    - too high --> miss behaviors

Time to Find Bottlenecks



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Thesis Contributions

- **Representation for the set of executions collected over the life of an application**
- **Techniques for automatically describing the structural and performance differences between two runs of a program**
- **Automated runtime performance diagnosis using historical data**

Acknowledgments

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- **Department of Energy**
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