Interoperability of Run-time Tools: Requirements and Concepts

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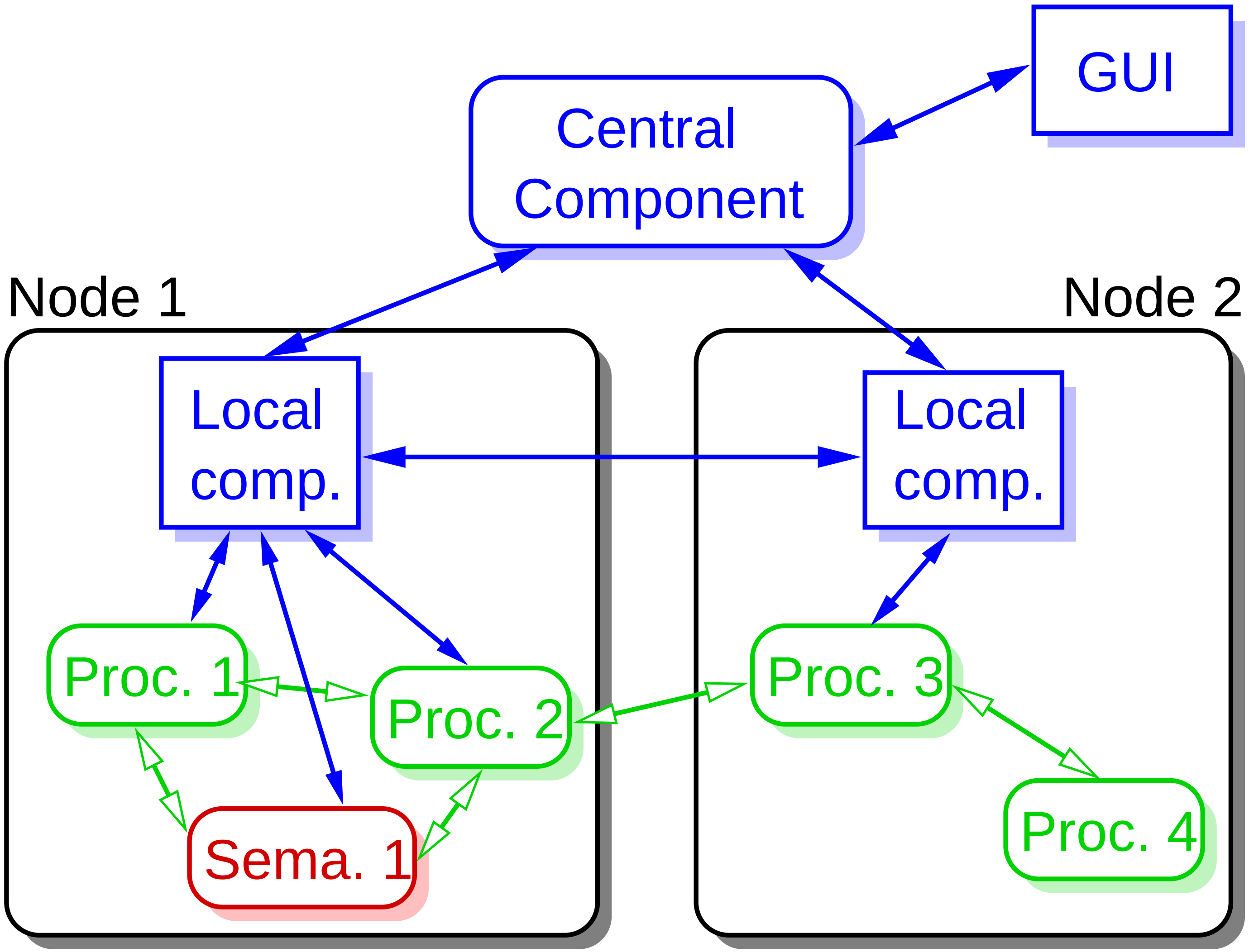
Agenda

1. Introduction
   - ➥ Run-time tools, interoperability
2. A Typical Scenario
   - ➥ debugger with random access to program states
   - ➥ required individual tools
3. Interactions Between Tools
   - ➥ requirements for a supporting infrastructure
   - ➥ existing infrastructures
4. Implementation of the Requirements in the OCM
5. Conclusions and Future Work

Run-Time Tools (On-line Tools)

- *Monitor*, *analyze* und *control* the execution of a distributed target system (HW+SW)
- E.g. debuggers, performance analyzers, load balancers, ...
- Common properties:
  - event based scheme of operation
  - distributed structure:
    - distributed monitor/control components (*monitoring system*)
    - (usually) centralized analysis component
    - centralized user interface (for interactive tools)

Typical Structure of a Tool



Interoperability

- Dazzling term with lots of different definitions:
  - polylingual software (e.g. C and Fortran)
  - communication of distributed programs (e.g. CORBA)
  - data bases (relational vs. OO)
  - ...
- An attempt of a more general definition:

  Interoperability is the ability of independent software components (not specifically designed for that purpose) to cooperate at a syntactic and semantic level.

1. Introduction (ctd.)

Interoperability of On-line Tools

- Multiple tools cooperate in the monitoring and control of the same target system

Motivation:

- For the user:
  - concurrent use of tools for different tasks
  - combined use can lead to additional benefits
- For the tool developer:
  - enhanced modularity
  - “factor out” target system dependencies

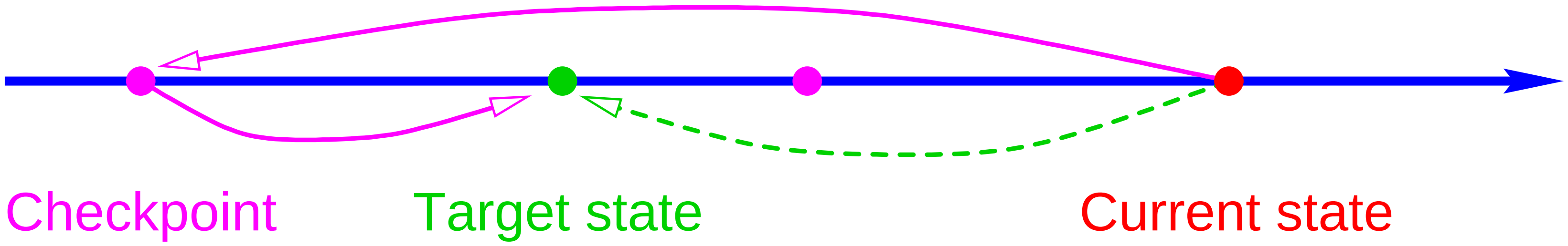
2. A Typical Scenario

Goal:

- Efficient debugging of long running programs
- Debugger with random access to (past) program states

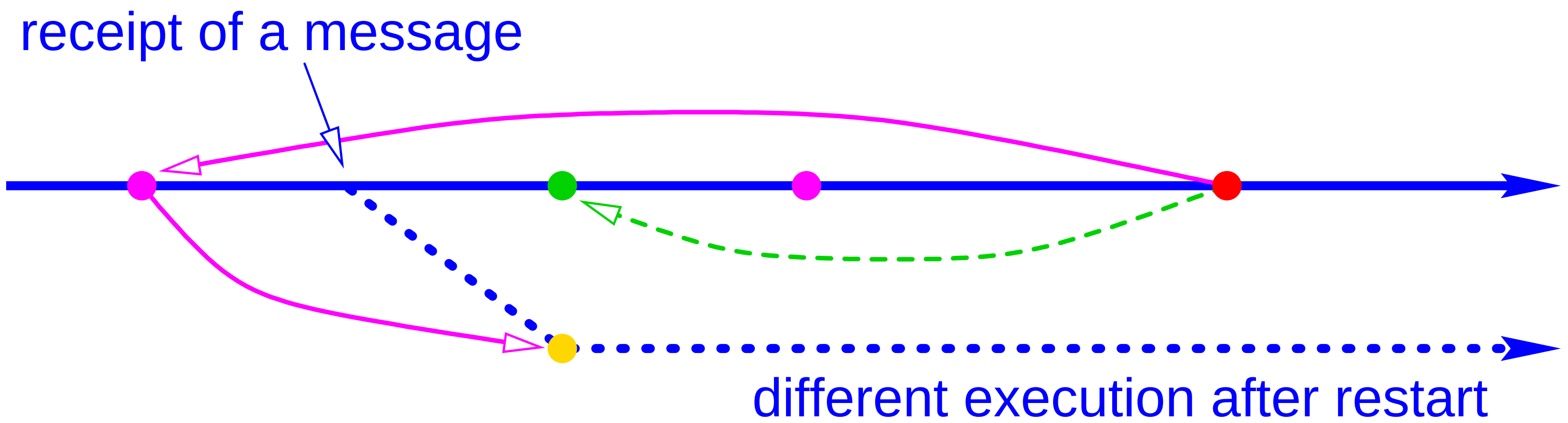
Idea:

- Periodically create global checkpoints
- Any desired program state can be reached by re-executing from the immediately preceeding checkpoint



Implementation

- Combine a debugger and a checkpointer
- Plus:
  - a visualizer as a means to specify the target state
  - a deterministic execution controller



2.1. The Debugger DETOP

Goal:

- Debugging of process sets

Implementation:

- Hierarchical, distributed design
- Local components use OS interfaces
  - process monitoring (e.g. signals, exceptions)
  - process control (e.g. stopping)
  - read / write process memory
- No support of programming model (PVM)
  - exception: use of PVM task identifiers

2.2. Checkpointing with CoCheck

Goal:

- Consistent checkpointing of communicating processes

Basis:

- Checkpointer for independent processes (Condor)
- Protocol to flush communication links
  - store all messages is receiver's address space

Implementation:

- Intercept most PVM calls
  - receive stored messages
  - translate task identifiers

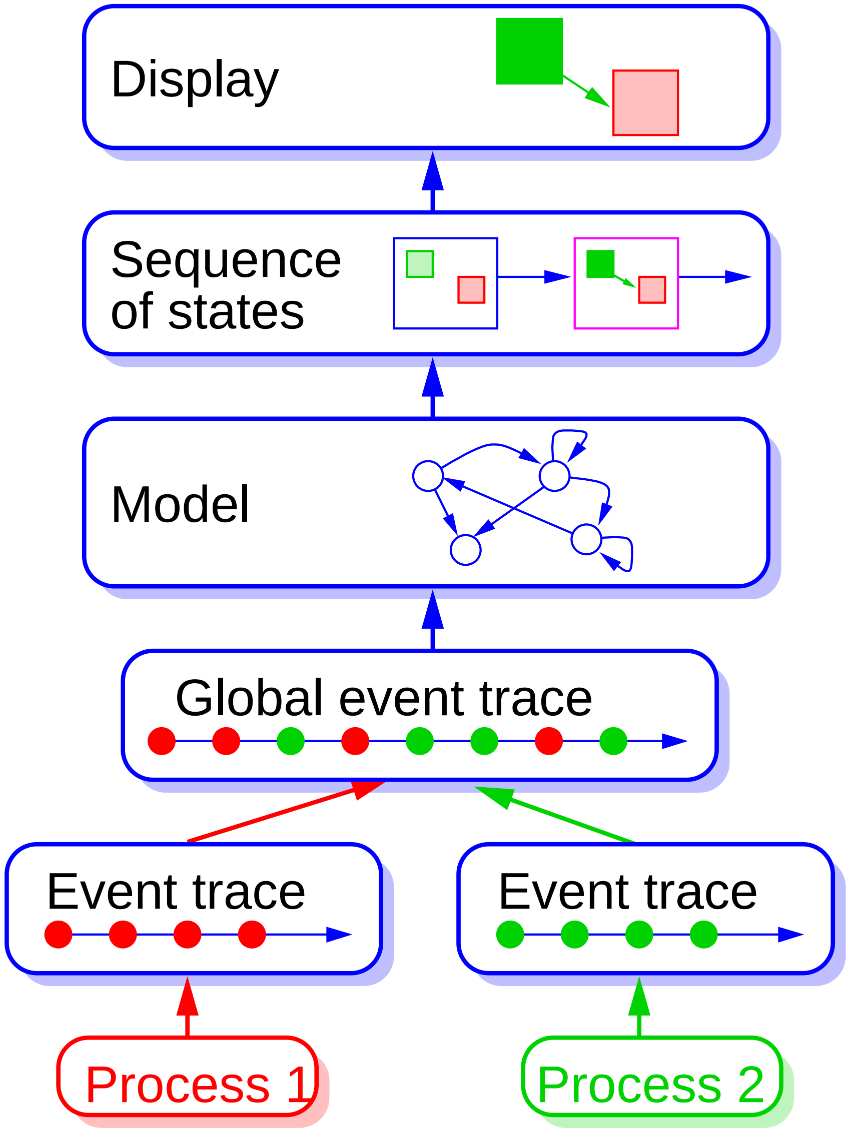
2.3. The Visualizer VISTOP

Goal:

- State based visualization of program execution

Implementation:

- Record calls to PVM library routines
- Model state of PVM
- Display a selected state in detail



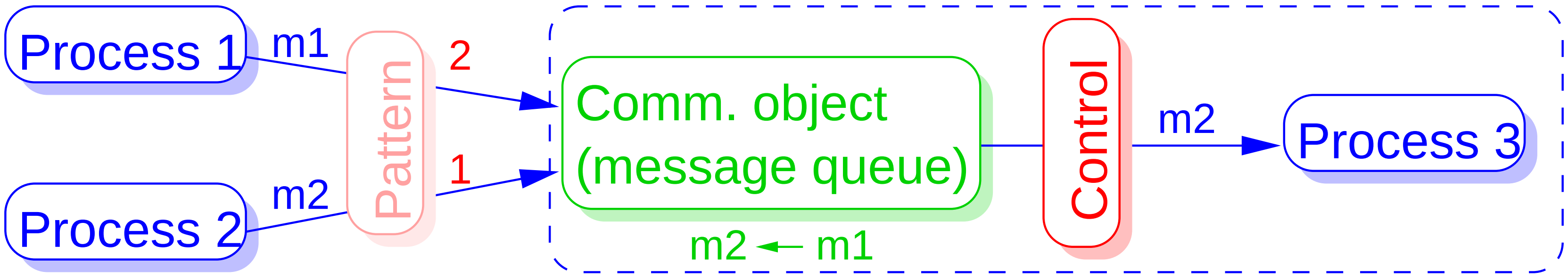
2.4. Deterministic Execution with Codex

Goal:

- Deterministic execution according to specified access patterns for communication objects

Implementation:

- Intercept PVM receive calls
  - check which message should be received according to the specified pattern
  - receive this message using a PVM call



3. Tool Interactions

Example 1: *Concurrent Accesses*

- CoCheck, VISTOP, and Codex monitor PVM calls in the same processes
- CoCheck and Codex modify parameters of these calls

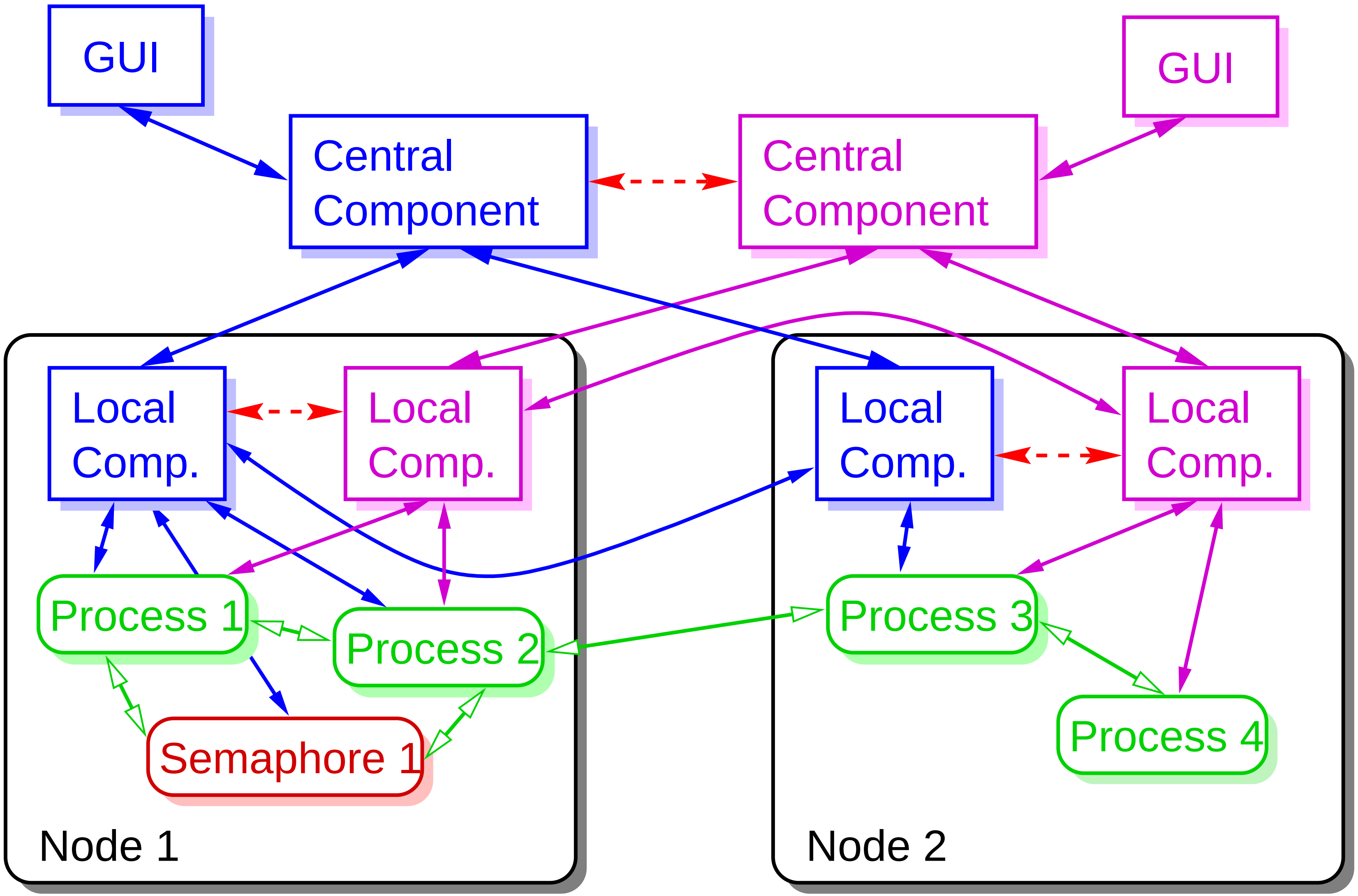
Lesson learned from OS's and DBS's

- We need a dedicated layer that coordinates the accesses (voluntary coordination doesn't work!)

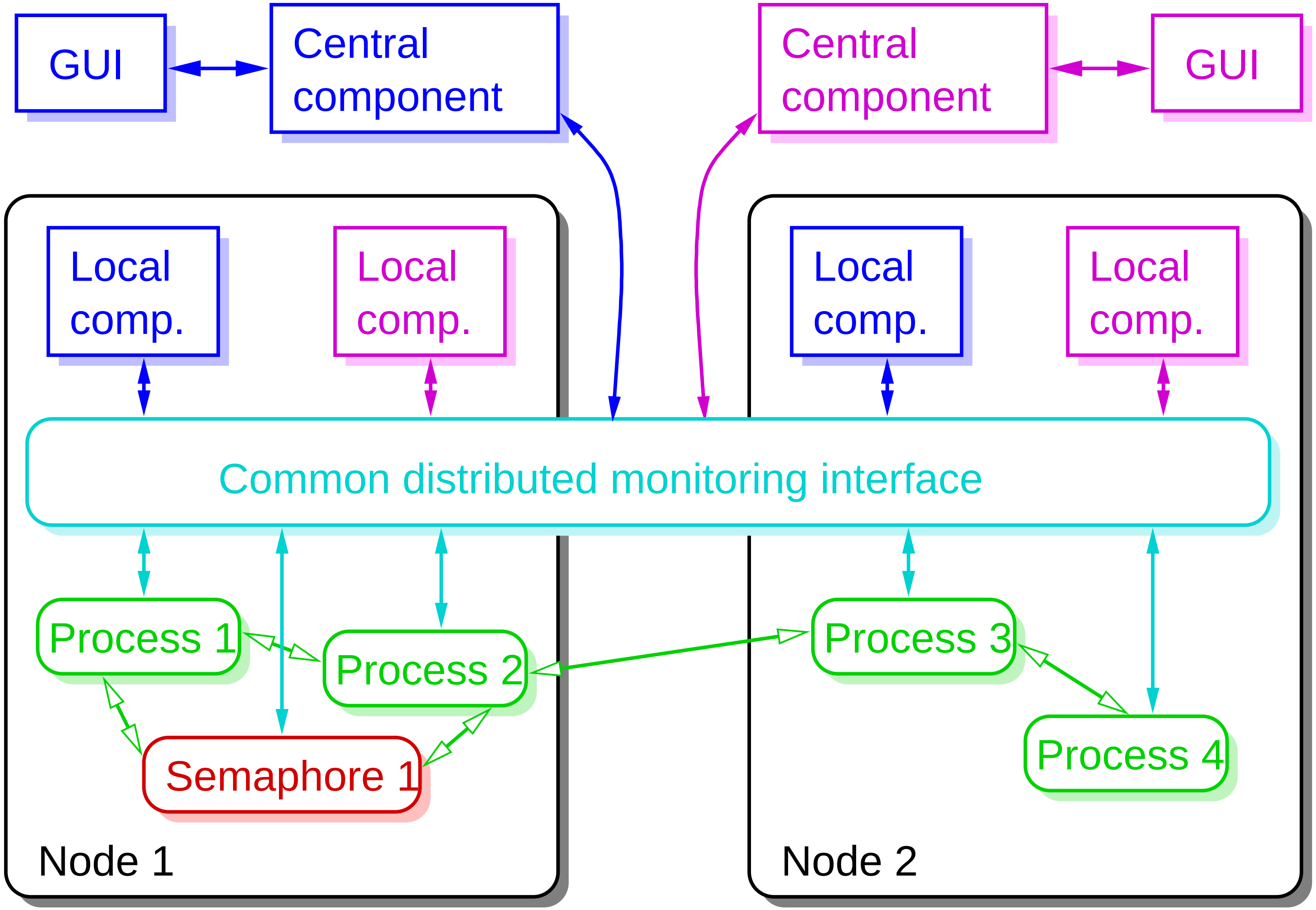
Requirement 1: *Common Monitoring System*

- We need a common open monitoring interface that coordinates accesses to the target system

Multiple Tools Monitoring the Same Target System



Common Interface to Target System



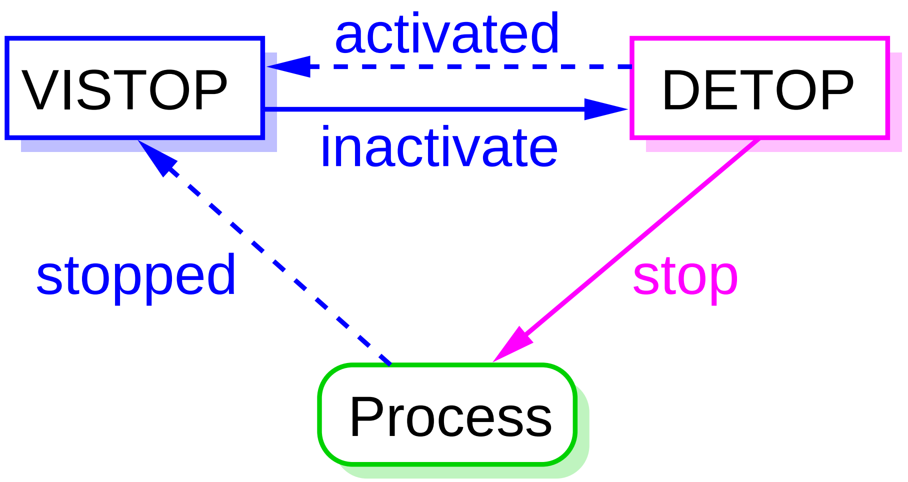
3. Tool Interactions (ctd.)

Example 2: *GUI Consistency*

- Tools should provide a consistent view of the system
- But:
  - DETOP always displays the current state
  - VISTOP can display an arbitrary (past) state
- Solution:
  - when DETOP is active: VISTOP shows current state
  - when scrolling back in VISTOP: inactivate DETOP
- In addition (due to event buffering):
  - when a process is stopped: VISTOP must read event buffer

Requirement 2: *Direct Interactions*

- Notification of events occuring in other tools
- Execution of actions in other tools



Requirement 3: *Indirect Interactions*

- Monitoring of transitions of object states (caused by other tools)

3. Tool Interactions (ctd.)

Example 3: *Transparency*

- Restart by CoCheck leads to new task identifiers
- Other tools should still see the old ones
- Identifiers are determined via monitoring interface

Requirement 4: *Intercepting Object Accesses*

- Mechanism to intercept object accesses of other tools
- Modification of requests and/or results

3. Tool Interactions (ctd.)

Example 4: *The Really Bad Case*

- VISTOP models the PVM receive queues
- Codex violates the FIFO semantics of these queues
  - order of receipt $\neq$ order of entry in queue
- Violates a basic assumption of VISTOP
- Requires extensive modifications of at least one tool

Recommendation:

- Avoid implicit assumptions
- Anticipate the presence of other tools

3. Tool Interactions (ctd.)

Summary: Requirements for an Environment Supporting Interoperable On-Line Tools

- *"Multi-user" interface for monitoring*
  - coordinates concurrent accesses to target system
- *Events and actions in other tools*
  - enable direct tool interactions
- *Monitoring of object state transitions*
  - enable indirect tool interactions
- *Interception and modification of object accesses*
  - maintain views of other tools

A Short Look at Existing Infrastructures

Communic. systems
Tool integration
Monitoring systems

	Corba	ToolTalk	PCTE	DPCL	DAMS	OCM
Monitoring Interface	-	-	o	+	+	+
Multiple Tools	+	+	+	+	+	+
Coordination	(+)	-	+	-	?	+
Direct Interactions	+	+	o	-	-	-
Events	o	+	-	-	-	-
Actions	+	+	-	-	-	-
Access Notification	-	-	o	-	+	o
Access Interception	-	-	-	-	-	-

4. Implementation in the OCM

The Distributed Monitoring System OCM

- Basic concepts:
  - object model of the target system
  - event / action paradigm
    - services: detection of events, access to objects
    - can be combined in conditional requests, e.g.:

```
thread_has_been_stopped([p_1]) :
    thread_get_backtrace([$thread], 0)
```

- Implementation:
  - distributed server processes with a hierarchical structure
  - event detection and execution of actions are also performed in the context of the target processes

4. Implementation in the OCM (ctd.)

“Multi-user” Interface for Monitoring

- OCM operates as a server
- Each tool has its private “environment”
  - e.g. definition of the target system
- Synchronization:
  - single actions on a single object are atomic
  - atomic multicast communication
  - requests can be globally locked

4. Implementation in the OCM (ctd.)

Events and Actions in Other Tools

- OCM supports event detection / action execution in the context of target processes
- Available events / actions detected at run-time (incl. interfaces)
- Necessary extension
  - include tools into object model of target system
    - tool object is derived from process object
    - services on processes are now also available on tools
  - removes distinction between tools and monitored system

4. Implementation in the OCM (ctd.)

Monitoring of Object State Transitions

- Can be realized via event services
- Currently only special cases, e.g. `thread_has_been_stopped`

Interception and Modification of Object Accesses

- Not yet available in the OCM

Common Feature

- Abstract: monitoring activities of the monitoring system
  - Problems: implementation, appropriateness of interface
- More specific: detection of object accesses

4. Implementation in the OCM (ctd.)

Detection of Object Accesses

- Goal:
  - generic detection mechanism
  - e.g. “`p_1` is stopped”, “TID of `p_2` is read”
- Requirements:
  - (unique) identification for object components
    - components must be part of OMIS object model
    - components must not overlap (i.e. no aliasing)
  - protected access mechanism to object components
    - ensure that all accesses are detected
    - manipulation of objects only by writing components

Detection of Object Accesses (ctd.)

- Problems:
  - implicit change of object components in OS calls
  - dynamic extensibility of OMIS/OCM
  - efficient implementation
- Implementation:
  - object $=$ dynamic array of pointers to static structures
  - access via C macros that include matching and notification
  - matching: compare with specifications in object class
- Overhead per access:
  - 6 memory reads, 3 conditional jumps (best case)

5. Conclusions and Future Work

- Combination of run-time tools is a promising way of implementing advanced tool environments
- Interoperability is impossible without a proper support environment (monitoring system)
- This is being more and more recognized
  - e.g. DPCL (IBM), DAMS (Univ. Lisbon, Portugal), ...
- Current work in OCM:
  - direct tool interactions
  - extended object model and detection of object accesses
- Future work: full implementation of the tool scenario