Development and Execution of Adaptive Component-based Applications

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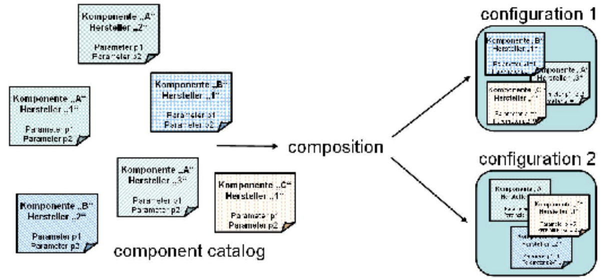
Outline

- Adaptive applications using alternative application configurations
- Dynamic reconfiguration in component-platforms (Java/.NET)
  - Reaching a reconfigurable state
  - Dynamic update and state transfer
- AOP tools for generating (re-)configuration specific logic
- Case study: adaptive control applications in a remote lab
- Conclusions

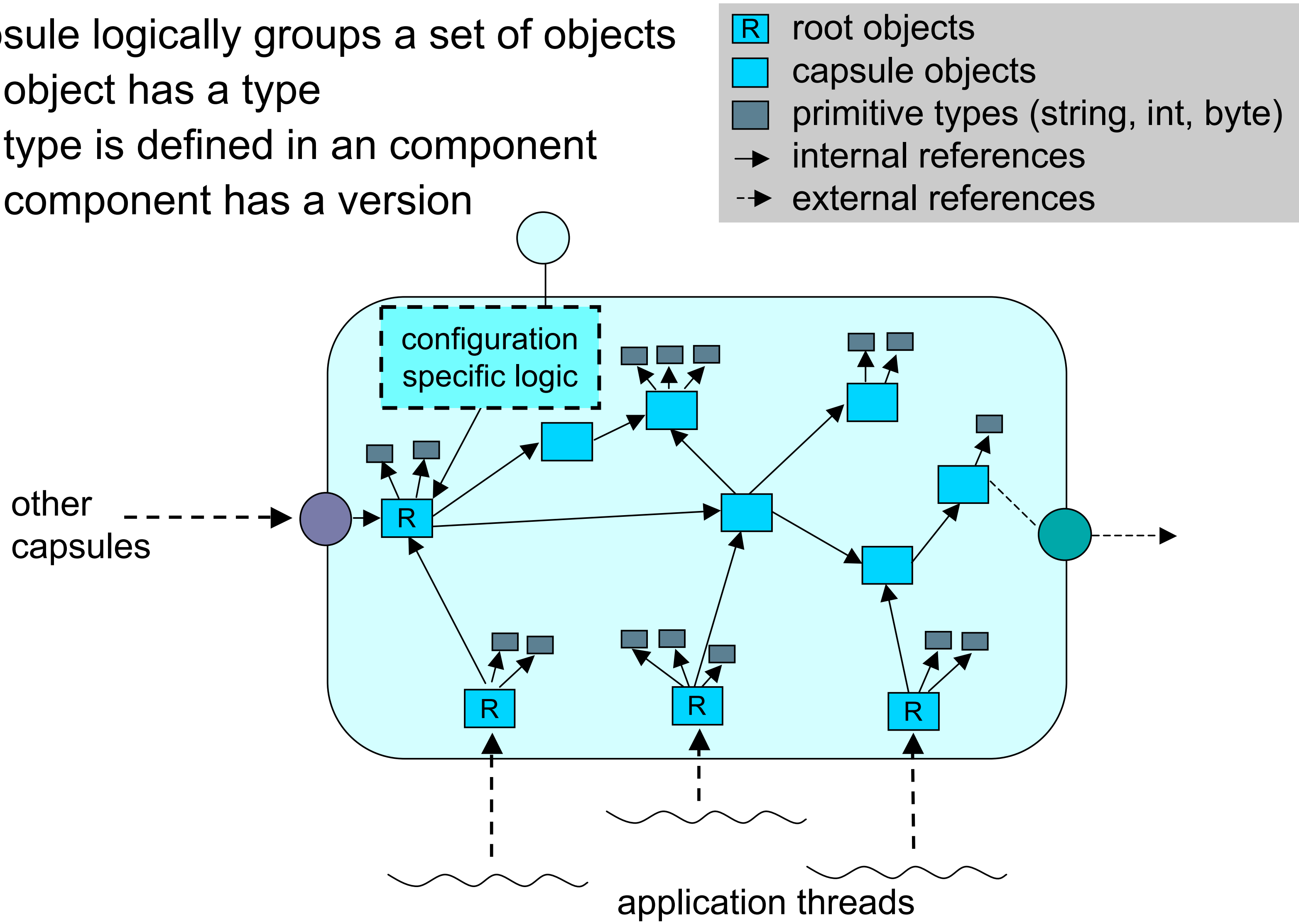
Adaptive Component-based Applications



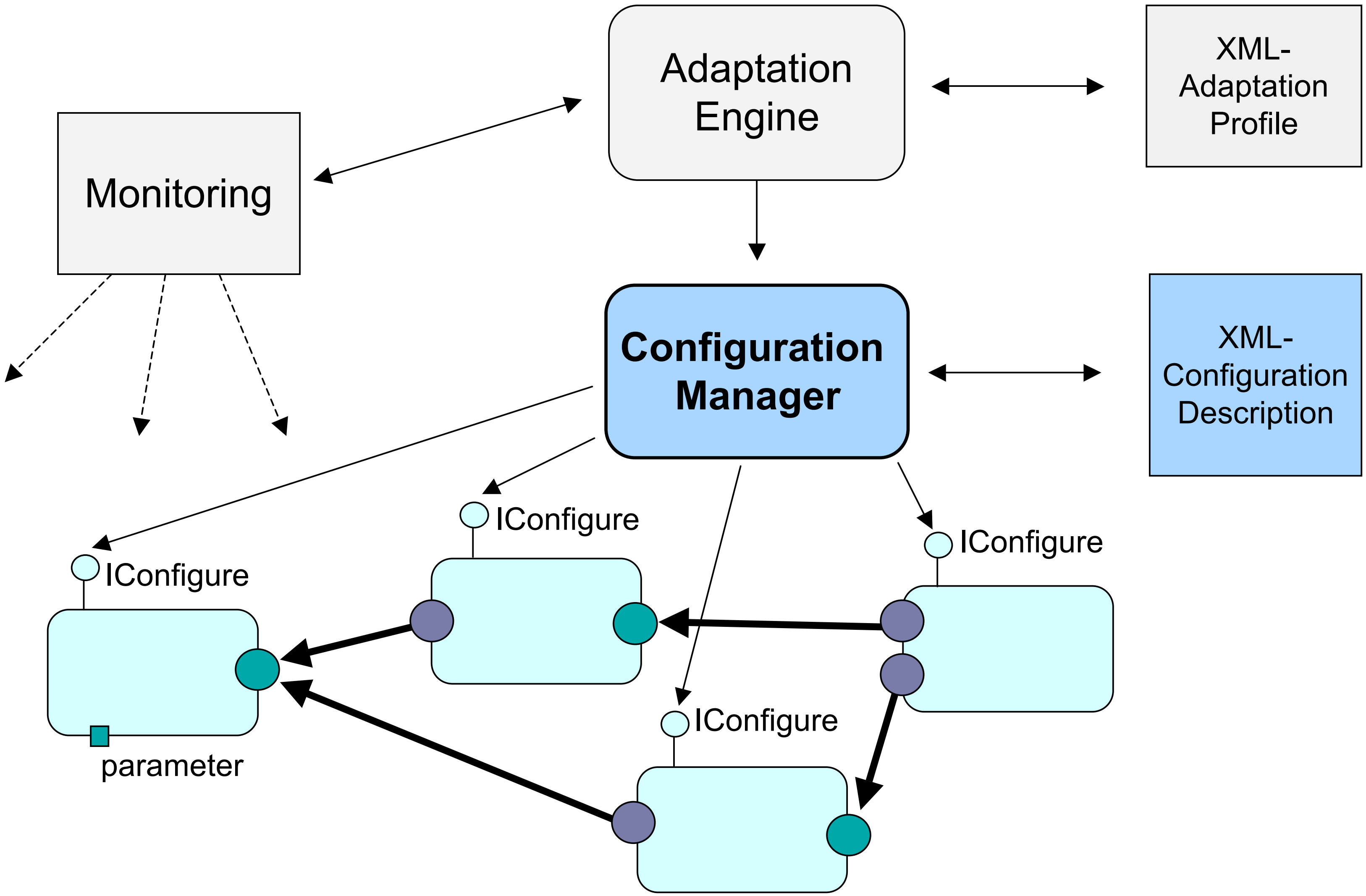
- Varying resources and context parameters demand adaptation
- Requirement: keep application properties (app.-level QoS) in user-desired range
- Components are units of deployment that can be composed by a third party
- Same interfaces can be implemented by multiple components having different properties
- **Different combinations of components (configuration)** can fulfill functional requirements of an application
- Applications can be composed **for different usage situations**
- **Solution**: Selection and activation of appropriate configuration for given environmental properties allow for adaptation
- **Challenge**: <u>Integrate dynamic reconfiguration in component platforms</u>

Capsules – Components at Runtime

- A capsule logically groups a set of objects
- Each object has a type
- Each type is defined in an component
- Each component has a version



The Adapt.Net Configuration Infrastructure

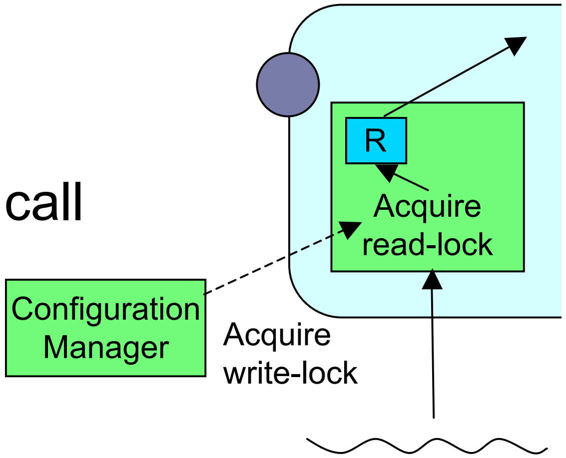


Adaptation through dynamic reconfiguration

- Application configuration:
  - Set of parameterized capsules
  - Set of connectors among capsules
  - Mapping to computers in a distributed system
- Dynamic reconfiguration includes:
  - Addition/removal of capsules
  - Changing capsule parameter
  - Migration(new location)/ updating (new logic) capsules
  - Changing connections between capsules
- Reconfiguration actions must remain consistency
  - No method execution during updates
  - No execution at capsules with unconnected sink capsules

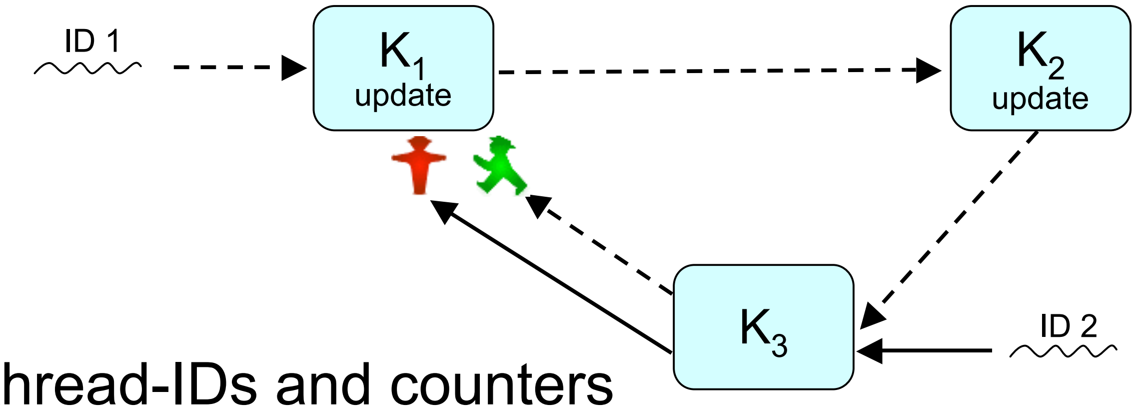
Reaching a reconfigurable state

- A capsule is reconfigurable if there is **no on-going method execution of capsules‘ objects on any threads‘ stack**!
- A reconfigurable state can be reached by:
  - Blocking new method calls from threads and other capsules
  - Waiting for all ongoing method calls to complete
- Acyclic graphs: connections can be blocked orderly
- Cyclic graphs: single threads must be blocked
- Reader-Writer-Locks for synchronization
  - Read-Lock is acquired for each normal method call
  - Write-Lock is acquired by the update logic
  - Usage of recursive locks for recursive calls



Reconfiguration of Distributed Applications

- RW-Locks in .NET- and Java-platform do not work distributed
- **Problem**: When blocking a thread it must not have on-going method calls on involved capsules



- **Solution**: logical thread-IDs and counters
  - Counter per capsule with on-going methods per thread
  - Update counter when entering/leaving a capsule via a root-object
  - During blocking: threads with no on-going method on involved capsules (counter in all capsule is zero) can be blocked

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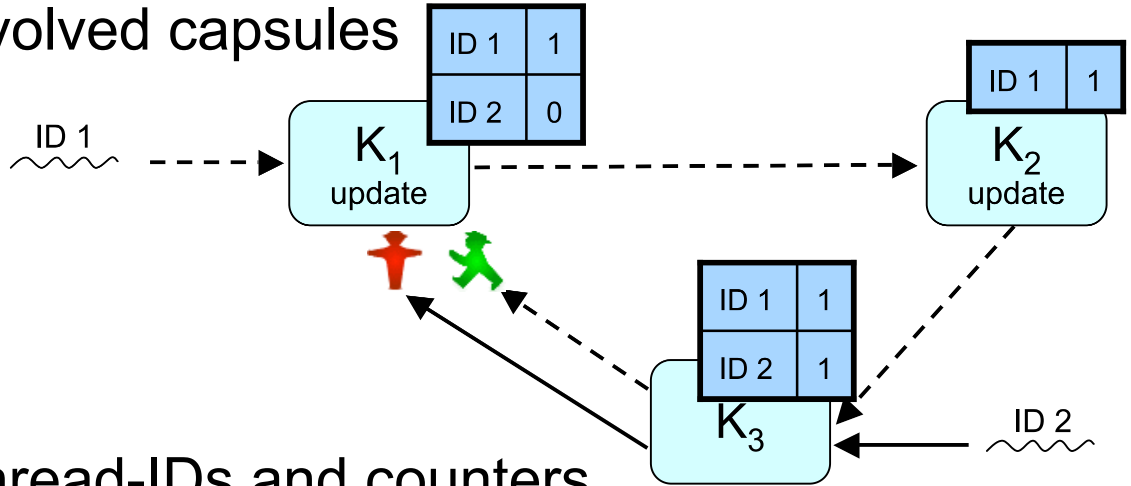

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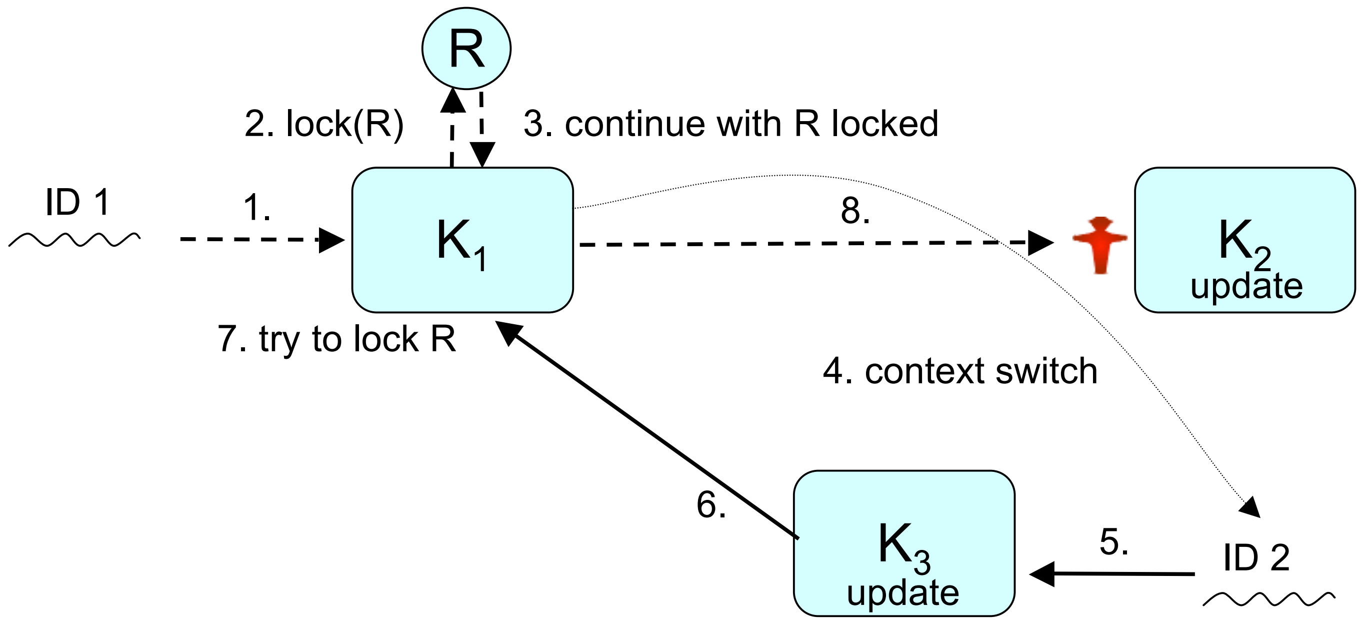
Application-specific synchronization

- In case of synchronization among application threads the algorithm must be extended
- All capsules on a path between involved capsules (the block-set) are added to the block-set



AOP tools and (re-)configuration specific logic

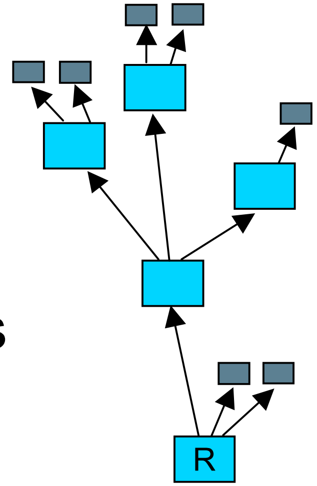
- Synchronization logic for dynamic reconfiguration
  - Management of capsules‘ counters
  - Blocking of threads
- Implementation of component‘s configuration interface
  - Set-up of communication connections
  - Parameterization
  - Initiation of blocking for dynamic reconfiguration
  - State transfer for migration and dynamic updates
- New programming model for marking connection end-points and parameters

```
public class Filter{
        [Parameter]
        int compression;
        [Connection]
        IStream sink;
```

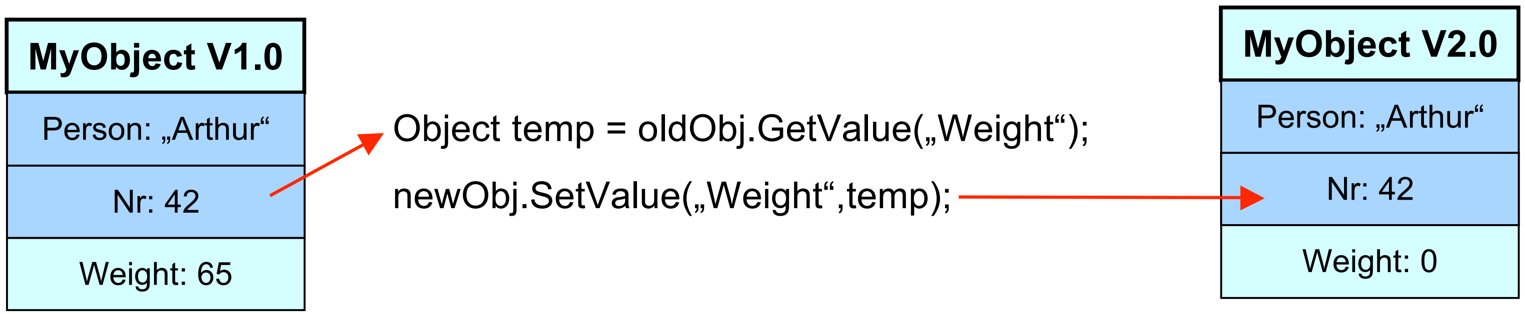
Dynamic Updates

- Complex reconfiguration operation
  - activation of new code (and data layout)
- Capsules have to be updated dynamically to:
  - Activate more appropriate algorithms at runtime
  - Integrate bug-fixed versions (remove security vulnerabilities)
  - Change graphical representation of adapted architecture
- Classes cannot be exchanged directly (in Java/.NET)
  - New versions of objects must be created
  - State must be transferred from old to new version
- Algorithm for reaching reconfigurable state used to apply update atomically

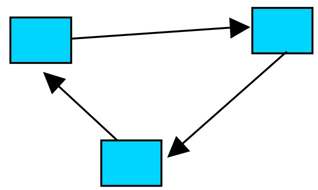
Traversing the Object Graph



- Start from all root objects
- For each field of all objects traverse all references
- In case of an update:
  - Create an instance of the new version
  - Copy the state by transferring all fields from the old to the new instance
  - For reference fields: traverse target first an install potential new version afterwards
- Usage of Reflection (GetFields, Set-/GetValue)

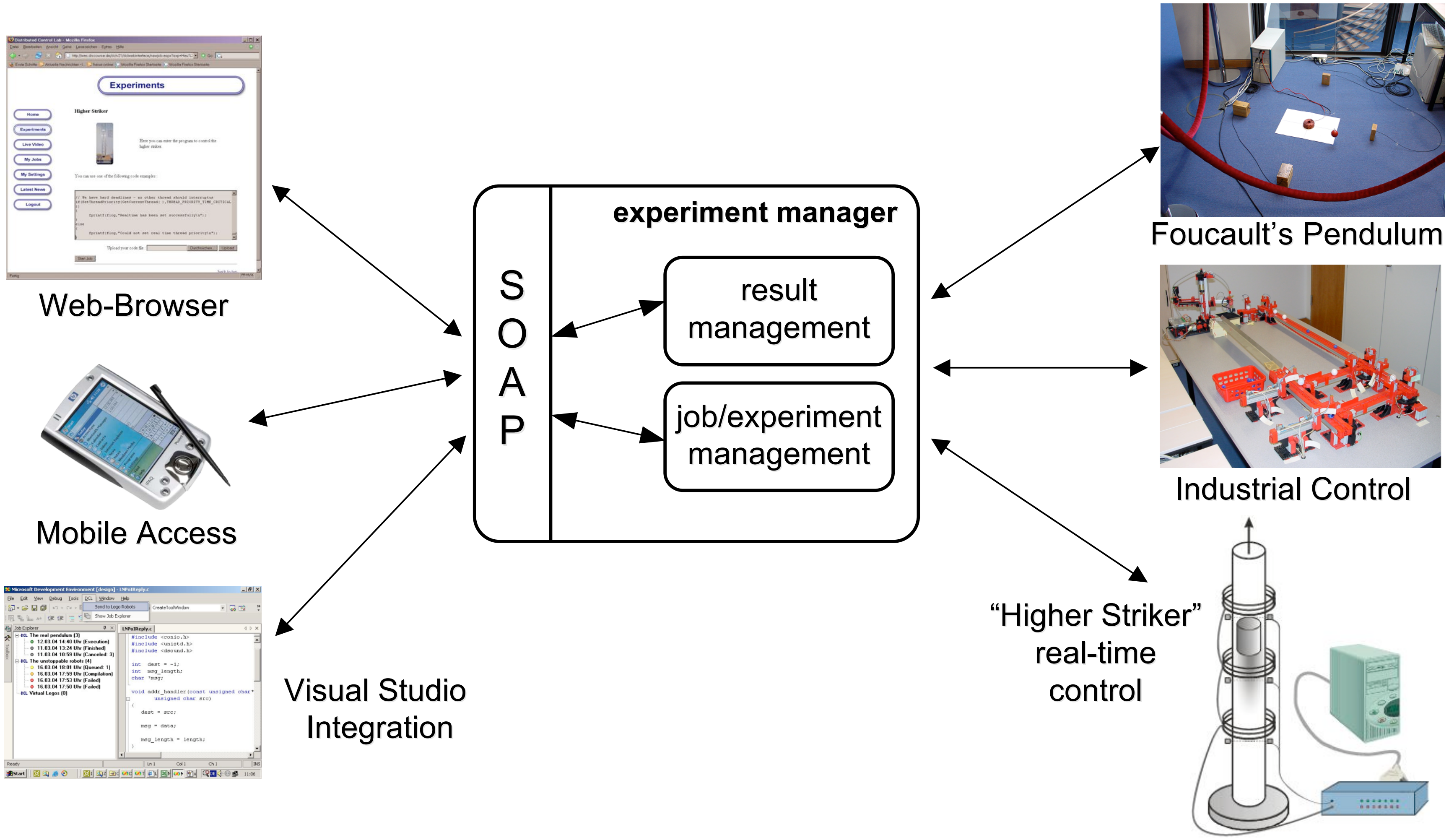


Traversing the Object Graph II



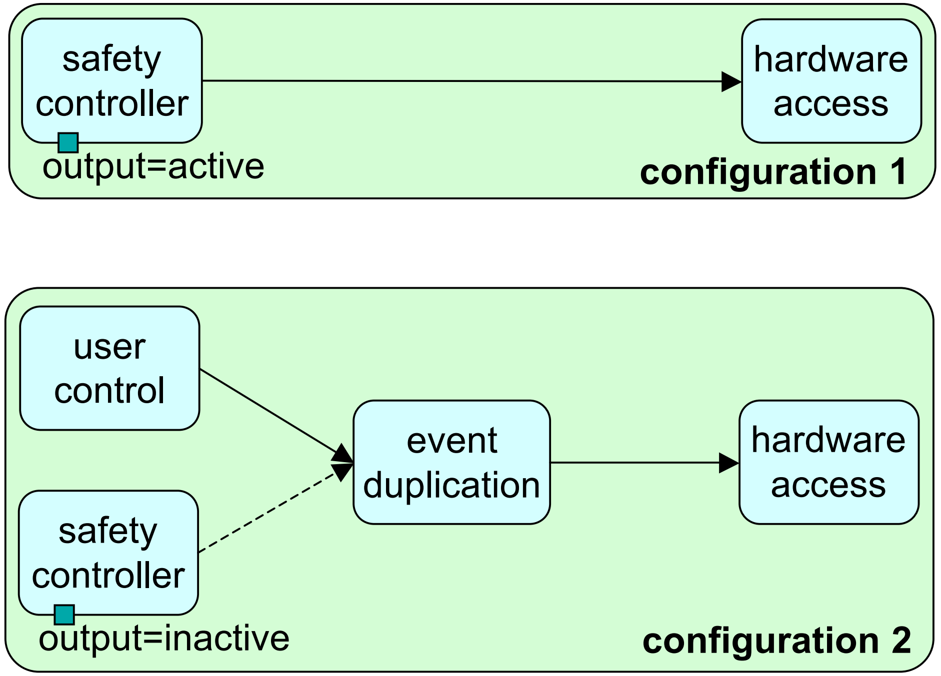
- Cycle recognition (visited nodes)
- Creation of new types (no constructor execution)
- Dynamic assembly loading (shadow copies)
- Arrays (update type and content)
- Delegates (update target and method)
- Generics (update bound types)
- Type and assembly objects
- Activation/deactivation/update of aspects
- State transformation for changed data layout

Case Study: Adaptive Control Applications in the Distributed Control Lab



Fault Tolerance and Security with dynamic reconfiguration

- Problem: malicious code submitted via the Internet
- Solution: execute an adaptive control application
  - Verified safety controller
- Observed parameters
  - Pendulums amplitude
  - Duration of job execution
  - State of user capsule (abnormal termination)



Conclusions

- Configurations can be composed/developed independently
  - Non-functional app.-properties can be tested for aimed situation
  - New configurations can be added (by a separate planner/...)
- Algorithm for dynamic reconfiguration of distributed multithreaded applications with cyclic dependencies
  - Low overhead for normal method execution
- Dynamic updates for activating alternative algorithms/ hot-fixes
  - Without manipulation of the virtual machine
- AOP capable of generating (re-)configuration specific logic
- Adaptive applications can be used for protecting experiment hardware in a remote laboratory environment

http://www.dcl.hpi.uni-potsdam.de

Further Reading

- **ReDAC - Dynamic Reconfiguration of distributed component-based applications with cyclic dependencies** Rasche, Andreas ; Polze, Andreas: Submitted to 11th IEEE International Symposium on Ob ject-Oriented Real-Time Distributed Computing, 5-7 Mai 2008, Orlando, Florida
- **Dynamic Updates of Graphical Components in the .NET Framework**

  Andreas Rasche and Wolfgang Schult, appeared in Proceedings of Workshop on Selbstorganisierende, Adaptive, Kontextsensitive verteilte Systeme in the frame of the GI/ITG-Tagung Kommunikation in Verteilten Systemen, Bern / Schweiz, 1. March 2007
- **Self-Adaptive Multithreaded Applications - A Case for Dynamic Aspect Weaving**

  Andreas Rasche, Wolfgang Schult, and Andreas Polze in ACM International Conference Proceedings of the 4th Workshop on Adaptive and Reflective Middleware (ARM 2005) Grenoble, France - November 28, 2005
- **Heterogeneous Adaptive Component-Based Applications with Adaptive.Net**

  Andreas Rasche, Marco Puhlmann and Andreas Polze in Proceedings of International Symposium on Object-oriented Real-time distributed Computing (ISORC), Seattle, Washington, USA, May 2005