Tool-Support for the Development of Adaptive Applications

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Outline

- Motivation
- Adaptive Application with the Adapt.Net Framework
  - Dynamic reconfiguration of component-based applications
  - Synchronization patterns
  - Creating configurable components
  - Runtime Infrastructure
- Building alternative configurations:
  - Integrating architectural patterns
- Concluding remarks
New Patterns for Developing Adaptive Applications

- Dynamic environments of modern software demand adaptation of software
- Self-configuration: change must be programmed
- State-of-the-art development realize adaptation application-specific

Improving development of adaptive software by:
- Identification of architectural patterns
- Tool-support for automatic integration of adaptation-specific concerns
- Support for developing alternative configurations
Adaptation: Building Blocks

Adaptation

Observation Monitoring

- Environment
  - Network, CPU, Battery
- Component properties
- Component behavior

React on changes

- Profiles
  - Map environmental conditions to according configurations

Reconfiguration
- Parameter
- Architecture
- Data
The Adapt.Net Framework

- Selection among alternative application configurations enables adaptive behavior
- Dynamic reconfiguration / runtime deployment
- Tool-support for creating reconfigurable applications
- Building alternative configurations: architectural patterns
- Runtime updates and migration
- Monitoring infrastructure: environmental properties, component parameter, component state
- Choosing configurations: Adaptation Profiles
Application Model

- Based on a work of J. Magee, J. Kramer, M. Wermelinger
- Components: Interconnected computational entities
  - Provide interfaces: in-ports
  - Require other components: out-ports
- Components connected by connectors
- No cycles in application topology graph
- A transaction virtually combines a number of bidirectional interactions between components
  - completes in bounded time
  - Initiator is informed about completion
- A transaction T1 is dependent on a subsequent transaction T2 (T1/T2) if its completion depends on the completion of this transaction
XML-Based Configuration Description

- “A Configuration of a component-based application denotes the set of its parameterized components and the connections among them.”

- Configuration description:
  - List of components
  - Component attributes
  - Component ports
  - Connectors

```xml
<configuration configurationname="cl">
  <component name="Viewer" args="" loadtype="OBJECT" assembly="MessageView.dll" assemblyVersion="..." access="" type="AdaptNet.ConfiguredObjectProxy.MessageView" location="localhost">  
  <port name="m_source" type="OUT" vartype="sample.proxy.MessageSource" />  
  <port name="default" type="IN" vartype="System.Object" />  
  </component>  
  <component name="Source" args="" loadtype="CorbaComponent" assembly="MessageView.dll" assemblyVersion="..." access="" type="sample.proxy.MessageSource" location="localhost">  
  <port name="default" type="IN" vartype="System.Object" />  
  <property name="encoding" value="UTF-8" type="System.String" />  
  </component>  
  <connector sourcecomponent="Viewer" sourceport="m_source" sinkcomponent="Source" sinkport="default" type="IOP" />
</configuration>
```
Configuration Infrastructure

Monitoring

Adaptation Engine

Configuration Manager

XML-Configuration Description

Adaptation Profile

IConfigure

IConfigure

IConfigure

IConfigure
Reconfiguration Algorithm

1. Loading of new components
2. Bringing application into reconfigurable state
   - Application consistency must be preserved during reconfiguration
   - Blocking all connections: Wait for all on-going transactions to complete; don’t allow initialization of new ones
   - Blocking must be ordered due to dependent transactions
3. Transferring state of migrated/updated components
4. Setting changed component parameters
5. Reconnecting components (create connectors)
6. Restarting component processing
7. Removing old components
Dynamic Reconfiguration

Configuration 1

Configuration 2

compression=30

A → B

A → C

D → B

A → C

compression=30
Dynamic Reconfiguration

1. Read XML-Description
2. Create new Component
3. Calculate Connections to block

Configuration Manager

Configuration 2
Dynamic Reconfiguration

Configuration Manager

Configuration 2
XML-Description

Compression=30
Dynamic Reconfiguration

Block new connections
Wait for on-going to complete

Reconfigurable State

Block Connection

Configuration Manager

Configuration 2
XML-Description

1
Read

2

3

4

5

6

A

B

C

D

Compression=30

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24.3.2006
Dynamic Reconfiguration

Configuration Manager

Configuration 2
XML-Description

Reconnect A
Connect D
compression=30

Read

1

7

7
Dynamic Reconfiguration

Configuration Manager

Configuration 2

XML-Description

1 Read

8 Restart processing

compression=30

A

D

B

C

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Blocking a Connection

- Component Code calls
  - **TransactionBegin:**
    - If(blocked) Wait(block_semaphore);
    - processing=true;
    - Wait(proc_semaphore);
  - **TransactionEnd:**
    - processing=false;
    - Release(proc_semaphore)

- Configuration interface
  - **BlockConnection**
    - blocked=true;
    - Wait(block_semaphore)
    - if(processing) Wait(proc_semaphore)
    - Release(proc_semaphore)
  - **Start** of Configuration interface
    - blocked=false;
    - Release(block_semaphore);

```c
int a = 3;
int b = 5;
int a = calc.Sub(a, b);
```

```c
Transaction.Begin();
b = calc.Add(1, b);
a = calc.Sub(a, b);
Transaction.End();
```
Reader-Writer Lock for Synchronization

- Synchronizes multiple read and concurrent write requests
- On write request: wait for all acquired read locks to complete
- New read requests are queued
- No synchronization needed for a read request if there is no write request
- Here we synchronize methods calls (reads) and reconfiguration requests (writes)
- Recursive read locks: threads already owning a read lock can acquire new read locks (for on-going method calls) despite pending write request
Configuration: A crosscutting concern

- Each component has to implement a configuration hook IConfigure:
  - Start component processing
  - Block connections
  - Set properties
  - Connect/disconnect out-going ports
  - Initialization / Finalization

- Implementation for IConfigure can be generated
  - Integrated into graphical development tool of Adapt.Net
  - Usage of Aspect-Oriented Development (AOP) tools
public class ConfiguredFilter: Filter, IConfigure {
    void SetProperty(string name, string val) {
        cval = Convert(val);
        this.GetField(name).SetValue(cval);
    }
    void Connect(string port, obj target) {
        this.GetField(port).SetValue(obj);
    }
    void BlockConnection(string conn) {
        mutex.Acquire();
    }
    void StartProcessing() {
        mutex.Release();
    }
}

public class Filter {
    [AdaptNet.Property]
    int compression;
    [AdaptNet.Connection]
    IViewer viewer;

    public void Send(byte[] data) {
        Transaction.Begin(viewer);
        viewer.Send(data);
        Transaction.End(viewer);
    }
}
CoFRA Infrastructure / Deployment

HOST A

C1

CoCo

configuration description

application assemblies

CoFRA

C2

CoCo

application level

cOMPONENT CONFIGURATORS

HOST B

C3

CoCo

application configuration

binary components

local assembly repository

CoFRA
The Component Configurator -
abstracting away CORBA, Java, and .NET

[Diagram showing interactions between CORBA, .NET, and Java environments with CoCo and CoFRA components.]
Component Type Loaders

- **Component Configurators** hide implementation details of component instances during runtime.
- Available **Component Type Loaders** manage components life cycle: loading, initialization, deletion, finalization.
- Existing Component Type Loaders and component start
  - **Simple Object**
    - Created using `new` language construct
  - **.NET Remoting Object**
    - Registration of Remote Service
  - **Process Component Type**
    - CreateProcess and Registration of Management Service Interface
  - **Java-based CORBA Object**
    - Initialization of CORBA runtime, object creation and registration
Connector Architecture

- Connector between components exchangeable during runtime
- Connector establishment implemented in IConfigure.Connect method
- .NET Remoting Connector
  - .NET-.NET
- Local Call Connector
  - Between simple Objects
- IIOP Connector
  - CORBA-.NET and CORBA-CORBA
- Planned connector patterns:
  - Tupelspace connector for online/offline configurations
  - Webservice connector to integrate available functionality
  - Gridservice connector to exploit available computing grids

```csharp
public bool Connect(string portname, string conntype, object options)
{
    if (conntype == "LOCAL")
    {
        FileInfon conn = this.GetFieldOfThis(portname);
        conn.SetValue(this, options);
        return true;
    }
    if (conntype == "REMOTE")
    {
        object[] params = (object[]) options;
        FileInfon conn = this.GetFieldOfThis(portname);
        string conntype = "tftp://" + params[1] + "/" + params[0];
        conn.SetValue(this, Activator.GetObject(conn.FieldType, conntype));
        return true;
    }
    if (conntype == "IIOP")
    {
        FileInfon conn = this.GetFieldOfThis(portname);
        object corbaRef = (object) options;
        conn.SetValue(this, corbaRef);
        return true;
    }
    ...
Architectural Patterns for Alternative Configurations

- Smart Connector pattern
- Voter Pattern
  - Compare output of 3 objects supporting the same interface
- Safe update pattern
  - Update a running object to a new version
- Load balancer pattern
- Migration pattern
  - Migrate an object from one host to another
- Filter, Compression, Encryption Pattern
- Simplex Pattern
  - Used in Foucault’s Pendulum
Grafical Support for Pattern Integration
The Simplex Pattern Applied
Foucault’s Pendulum in the Distributed Control Lab

Configuration 1: safety controller
- Safety Controller

Configuration 2: user program (cold standby)
- Safety Controller
- User Program

Configuration 3: user program (warm standby)
- Safety Controller
- Event Duplicator
- User Program

USB-Driver
Event Queuing
Adaptation Profiles
Dynamic Reconfiguration & State

- Realizing component updates
- Component migration for mobility
Component Migration: C from H1 to H2

1. Read Configuration
2. Analyze File Dependencies
3. Transfer Files
   - c.dll
   - c1.dll
   - c2.dll
4. Instantiate C
5. Block Connections

Host 1
- Configuration Manager
- Configuration Description

Host 2
- Configuration Manager

A
B

Component C moves from host 1 to host 2.
Component Migration: C from H1 to H2

1. Save State
2. Transfer State
3. Restore State
4. Reconnect C
5. Restart Processing
6. Remove old C
7. Configuration Manager
8. Configuration Manager
9. Configuration Manager
10. Configuration Manager
11. Configuration Manager
Component Updates: An Algorithm

- Bring components into reconfigurable state
- Traversal of whole object graph
- Member-wise investigation of nodes using Reflection
- Investigation of each node for update
- Update specified via assembly mapping:
  - Specification of updated assemblies
- State transfer via member-wise close
Component Update State Transfer II

- Cycle recognition – visited nodes:
  
  ```c
  bool firstTime;
  long id = idGenerator.GetId(node, out firstTime);
  if(!firstTime)
    return visitedNodes[id];
  ```

- Save updated nodes in visited nodes list

- Investigation of all arrays
  - Traverse all reference type members
  - Create new version in case of base-type update
  - Copy content of updated arrays
Component Update: Delegates

- Function pointers in .NET
- Traverse all targets of delegates
- Multicast delegates contain multiple delegates

Updating multicast delegates:
- Extract all delegates from multicast delegate
- Create new versions: `Delegate.CreateDelegate`
- Combine to new multicast delegate

```csharp
class Delegate
{
    private System.Type target_type;
    private object m_target;
    private string method_name;
    private int method_ptr;
}
```
Finding Optimal Configurations

- **R**: Available Resources
  - CPU
  - Battery Power
  - Network Bandwidth

- **Q**: Non-functional Properties (QoS)
  - Video Resolution
  - Framerate
  - Audio Bandwidth

- **User Utility**: \( UU: Q \rightarrow [0..1] \)

- **Resource Profile**: \( RP: R \rightarrow Q \)
Solving the Configuration Problem
Ongoing Work

- Dynamic reconfiguration / adaptation in real-time systems
- Service Integration in ad-hoc networks
  - Finding best service available
- Beyond adaptation profiles: Closed looped control of application parameter
- Resource manager for handling concurrent applications
- Integrated solution of the configuration problem
  - Creation of an optimal configuration out of a set of given software components
- Dynamic Aspect Activation
Conclusions

- Development of adaptive applications can be improved by:
  - Tool-support for building alternative application configurations
  - Reusable Runtime Infrastructures
  - Tool-based generation of configuration-specific code
  - Identification of patterns for dynamic reconfiguration, migration, monitoring, deployment improves development productivity
Tool-Support for the Development of (Self-)Adaptive Applications

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Pattern: Dynamic Aspect Activation

- Loading of new configurations containing interwoven aspect code
- Allows for activation / deactivation of aspects with very small runtime overhead
- Integration Security aspects in unsafe environments
- Dynamic Trace Code Activation
The Server-side approach: dynamic proxies

```java
public class A {
    ...
    IService b = ...
    b.method1();
    ...
}
```

```java
class Proxy:IService{
    public method1() {
        //track call start
        inst.method1();
        //track call stop
    }
    ...
}
```

```java
class B:IService {
    public method1() {
        ...
    }
    ...
}
```

Multithreaded Application

Reconfigurable Component

Client Components

Service Configuration

dynamic aspect code