Fractal in Java

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The Fractal Component Model

From the previous Webinar…

- FT R&D, INRIA
- open source
- http://fractal.ow2.org

- main target domains: system and middleware
- general enough for any other application domain
- fine-grained (wrt EJB or CCM), close to classes
- lightweight
- independent from programming languages

- homogeneous view of layers (OS, middleware, services, applications)
  - Fractal everywhere
- in order to unify and facilitate
  - design, development, deployment, management
Outline

1. Developing with Fractal in Java
   1.1 Fraclet
   1.2 Fractal ADL
   1.3 Fractal API

2. Platforms
   2.1 Julia
   2.2 AOKell

3. Conclusion
1. Developing with Fractal in Java

3 complementary tools

- **Fraclet**
  - annotation based programming model

- **Fractal ADL**
  - XML-based architecture description language (ADL)

- **Fractal API**
  - Java API for dynamically
    - introspecting
    - reconfiguring
1.1 Fraclet

Main annotations

- annotation based programming model (Java 5 or XDocLet)
- @Component
  - apply on the implementation class of a component
  - 2 optional parameters
    - name : component name
    - provides : services provided by the component
- @Requires
  - apply on a field : reference to the required service (of type T)
    - field of type T for singleton (1-1) references
    - field of type Map<String,T> for multiple (1-n) (COLLECTION) references
  - 3 optional parameters
    - name : component interface name
    - cardinality : SINGLETON (default) or COLLECTION
    - contingency : MANDATORY (default) or OPTIONAL
Example: Hello World in Fractal

- root composite component with 2 sub-components
- sub-component callee providing an interface
  - named s
  - of type `interface Service { void print(String msg); }`
- sub-component caller providing an interface
  - named r
  - of type `java.lang.Runnable` (*de facto* Fractal convention)
  - delegated at the level of the composite component
- caller requires the service provided by callee
1.1 Fraclet

Hello World in Fractal – The Callee Component

package hw;

@Component(
    provides=
        @Interface(name="s",signature=Service.class) )
public class CalleeImpl implements Service {
    public void print( String msg ) {
        System.out.println(msg);
    }
}

Hello World in Fractal – The Caller Component

```java
package hw;

@Component(
    provides=
        @Interface(name="r",signature=Runnable.class) )
public class CallerImpl implements Runnable {

    @Requires(name="s")
    private Service service;

    public void run() {
        service.print("Hello world!");
    }
}
```
1.1 Fraclet

Hello World in Fractal – Assembling

Fractal ADL

<definition name="hw.HelloWorld">

  <interface name="r" role="server"
    signature="java.lang.Runnable" />

  <component name="caller" definition="hw.CallerImpl" />

  <component name="callee" definition="hw.CalleeImpl" />

  <binding client="this.r" server="caller.r" />
  <binding client="caller.s" server="callee.s" />

</definition>
1.1 Fraclet

Hello World in Fractal – Running

- **Command line**

- **Eclipse**
  - F4E
  - Fractal project
  - component programming
  - ADL editing
  - [http://fractal.ow2.org/f4e](http://fractal.ow2.org/f4e)
Hello World in Fractal – Running

- GMF based graphical editor
1.1 Fraclet

Hello World in Fractal – Running

Console

Fracal Explorer
- runtime tree view
- start/stop
- launch
- introspect
- reconfigure
1.1 Fraclet

In a nutshell

- component implementation in Java
- annotation for component related metadata
- assembling with Fractal ADL
- execution
1.1 Fraclet

Other Fraclet annotations

- @Interface : provided interface
- @Attribute : component property
- @Lifecycle : lifecycle callbacks
- @Controller : control interface reference injection
- @Node : virtual node for distributed programming
- @Membrane : controller descriptor

http://fractal.ow2.org/fraclet for more details
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1.2 Fractal ADL

XML-based language for defining & configuring
a Fractal component-based system

Basic DTD for defining
- interface
- component (composite and primitive)
- binding

Describe the initial architecture of a Fractal component-based system

Toolchain
- to parse assembly files
- to instantiate the corresponding component-based system
- extensible
  - the DTD and the toolchain can be extended with new tags & processing components
1.2 Fractal ADL

Basic notions
- root definition
- interface
- component

Advanced notions
- extended definition
- component sharing
- parameterized definition
- toolchain
1.2 Fractal ADL

Root definition

- **XML file with the .fractal extension**

- **Tag <definition> to define a top-level component for the system**
  - 0 or n <interface> for defining interfaces
  - 0 or n <component> for defining sub-components
    - primitive or composite inserted in the top-level component
    - each component can be
      - defined inlined in the file
      - defined in a external file
  - 0 or n <binding> for defining bindings between sub-components
Hello World in Fractal – Revisited

Fractal ADL

```xml
<definition name="hw.HelloWorld">
    <interface name="r" role="server"
               signature="java.lang.Runnable" />
    <component name="caller" definition="hw.CallerImpl" />
    <component name="callee" definition="hw.CalleeImpl" />
    <binding client="this.r" server="caller.r" />
    <binding client="callee.s" server="callee.s" />
</definition>
```

External definition in file CallerImpl.fractal

External definition in file CalleeImpl.fractal
1.2 Fractal ADL

Interface

```xml
<interface
    name = "r"
    role = "server"
    signature = "java.lang.Runnable"
    cardinality = "singleton"
    contingency = "mandatory"
/>
```

<!--ELEMENT interface EMPTY -->
<!--ATTLIST interface
    name CDATA #REQUIRED
    role (client | server) #IMPLIED
    signature CDATA #IMPLIED
    cardinality (singleton | collection) #IMPLIED
    contingency (mandatory | optional) #IMPLIED -->
1.2 Fractal ADL

Component

- defined in an external .fractal file
- defined inlined
  - interfaces
  - content
    - primitive Java implementation class
    - composite sub-components + bindings
  - attribute(s)
    - components can export properties
    - via an interface named attribute-controller
    - the interface provides setter/getter for managing properties
    - Fractal ADL provides tags for configuring their initial value
- controller descriptor
  - the membrane type associated with the component
1.2 Fractal ADL

Component

Example 1: primitive component

```xml
<component name="caller">
  <interface name="r" role="server" signature="java.lang.Runnable" />
  <interface name="s" role="client" signature="hw.Service" />
  <content desc="hw.CallerImpl" />
  <attributes signature="hw.ServiceAttributes">
    <attribute name="header" value="->" />
    <attribute name="count" value="1" />
  </attributes>
</component>
```
1.2 Fractal ADL

Component

Example 2: composite component

<definition name="HelloWorld">
  <interface name="r" role="server" signature="java.langRunnable" />
  <component name="caller" definition="hw.CallerImpl" />
  <component name="callee" definition="hw.CalleeImpl" />
  <binding client="this.r" server="caller.r" />
  <binding client="caller.s" server="callee.s" />
</definition>
1.2 Fractal ADL

Binding

- a reference between a required interface and a provided interface

```xml
<binding client="this.r" server="caller.r" />
```

- client: the source (required) interface
- server: the target (provided) interface
- syntax
  - "componentName.interfaceName"
  - componentName can be this (current component)

```xml
<!ELEMENT binding EMPTY >
<!ATTLIST binding client CDATA #REQUIRED server CDATA #REQUIRED >
```
A (slightly) more complex example with collection interfaces

<definition name="hw.HelloWorld">
  <interface name="r" role="server" signature="java.lang.Runnable" />
  <component name="caller">
    <interface name="r" role="server" signature="java.lang.Runnable" />
    <interface name="cols" role="client" cardinality="collection" signature="hw.Service" />
    <content desc="ClientImpl" />
  </component>
  <component name="s1"> ... </component>
  <component name="s2"> ... </component>
  <binding client="this.r" server="caller.r" />
  <binding client="caller.cols1" server="s1.s" />
  <binding client="caller.cols2" server="s2.s" />
</definition>
Basic notions

- root definition
- interface
- component

Advanced notions

- extended definition
- component sharing
- parameterized definition
- toolchain
1.2 Fractal ADL

Advanced Notion – Extended Definition

- reuse and extend existing definitions

Good practise
- separate the definition of a component type from its implementation

```xml
<definition name="hw.CallerType">
  <interface name="r" role="server" signature="j.lRunnable" />
  <interface name="s" role="client" signature="hw.Service" />
</definition>

<definition name="hw.Caller" extends="hw.CallerType">
  <content class="hw.CallerImpl" />
</definition>
```
1.2 Fractal ADL

Advanced Notion – Component Sharing

- a component with several parent components
- first definition
- the next ones reference the first one

```xml
<definition name="foo">
  <component name="a">
    ... </component>
  <component name="aa">
    ... </component>
</component>

<component name="b">
  <component name="aa" definition="a/aa" />
</component>

</definition>
```
1.2 Fractal ADL

Advanced Notion – Parameterized Definition

- arguments may be declared when defining an architecture
- used in the definition with ${...}

<definition name="hw.Client" arguments="itfname,impl" >

  <interface name="r" role="server" signature="..." />
  <interface name="s" role="client" signature="${itfname}" />

  <content class="${impl}" />

</definition>
1.2 Fractal ADL

Advanced Notion – Toolchain

XML file(s) -> Front-end: XML parsing -> Back-end: dynamic

<<uses>> -> Execution

<<uses>> -> Platform

<<generate>> -> .java files

Back-end: static
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1.3 Fractal API

Fractal is a dynamic component model

- components and assemblies are runtime entities
  - applications can be dynamically reconfigured

Introspection and modification

- binding controller
- component
  - introspection
    - hierarchy: content controller and super controller (parent)
    - component: interface discovery
  - modification
    - dynamic instantiation
    - hierarchy: content controller and super controller (parent)

- API Fractal
1.3 Fractal API

- lightweight (16 interfaces, <40 methods)

Illustration: Setting up the Hello World Example with the API

1. Create interface & component types
2. Instantiate components
3. Assemble components
   1. Create hierarchies
   2. Bind components
4. Start the application
1.3 Fractal API
1.3 Fractal API

1. Create interface & component types

Interface type

- name
- signature (Java interface)
- 1 bool : true = client
- 1 bool : true = optional
- 1 bool : true = collection

Component type

- array of interface types
1.3 Fractal API

1. Create interface & component types

- Retrieve the TypeFactory

```java
Component boot = Fractal.getBootstrapComponent();
TypeFactory tf = Fractal.getTypeFactory(boot);
GenericFactory cf = Fractal.getGenericFactory(boot);
```

- Create a component type for the root composite

```java
ComponentType rootType = tf.createFcType(new InterfaceType[] {
    tf.createFcItfType(  
    "r",  // name
    "java.langRunnable",  // Java signature
    false,  // server (provided)
    false,  // mandatory
    false)  // singleton
});
```
1.3 Fractal API

1. Create interface & component types

- Create component type for the caller and callee components

```java
ComponentType callerType = tf.createFcType(new InterfaceType[] {
    tf.createFcItfType(
        "r", "java.lang.Runnable", false, false, false),
    tf.createFcItfType(
        "s", "hw.Service", true, false, false)
});

ComponentType calleeType = tf.createFcType(new InterfaceType[] {
    tf.createFcItfType("s", "hw.Service", false, false, false)
});
```
1.3 Fractal API

2. Instantiate components

- Instantiate the root composite

Component rootComp = cf.newFcInstance(
    rootType, // component type
    "composite", // membrane
    null); // implementation

- Instantiate the primitive components

Component callerComp =
    cf.newFcInstance(callerType, "primitive", "hw.CallerImpl");
Component calleeComp =
    cf.newFcInstance(calleeType, "primitive", "hw.CalleeImpl");
1.3 Fractal API

3. Assemble components

- Create hierarchies
  - insert the Caller & Callee component in the root composite

```java
Fractal.getContentController(rootComp).
    addFcSubComponent(callerComp);
Fractal.getContentController(rootComp).
    addFcSubComponent(calleeComp);
```
3. Assemble components

- Create bindings

```java
Fractal.getBindingController(rootComp).bindFc("r", callerComp.getFcInterface("r"));

Fractal.getBindingController(rootComp).bindFc("s", calleeComp.getFcInterface("s"));
```
1.3 Fractal API

4. Start the application

- Start the root composite
  - recursively start sub-components
- Invoke the provided interface on the root composite

Fractal.getLifeCycleController(rootComp).startFc();
((Runnable)rootComp.getFcInterface("r")).run();
1.3 Fractal API

Conclusion on Fractal API

- intuitive
- no complexity
- powerful
- base for other tools (Fraclet, Fractal ADL, etc.)

- verbose
- slightly underspecified
  - e.g. getFcInterface(), lookupFc() return Object (not Interface)
  - membrane descriptor are Object

- leave the API open to extensions to the model
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2. Platforms

- several platforms
  - 3 for Java
    - Julia: reference implementation
    - AOKell: aspect-oriented implementation
    - ProActive: implementation for grid computing
  - 3 for C (Think, Cecilia, MNF)
  - 1 for C++ (Plasma)
  - 1 for SmallTalk (FracTalk)
  - 1 for .NET (FractNet)

- several platforms for different needs
2. Platforms

Concepts associated with platforms

- **control membrane**
  - hosting infrastructure for a component
  - provide non-functional services
  - implements the component semantics
  - aka container in other component framework (e.g. EJB)
  - composed of a set of controllers

- **controller**
  - provide a particular non functional service

- **control interface**
  - the service provided by a controller

- **interceptors**
  - filter communications

- **content**
  - the business code of the component
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2.1 Julia

- reference implementation of the Fractal component model
- http://fractal.ow2.org/julia

- demonstrate adequation/feasibility of the specifications
- extensible framework for programming control membranes
- designed with the following objectives
  - minimize memory footprint of the control membranes
  - minimize runtime overhead of the control membranes
2.1 Julia

Modular organization of the platform

1. fractal-api : Fractal API
2. julia-runtime : Julia internal API
3. julia-asm : bytecode generation framework
   - based on the ASM bytecode engineering library
   - implements a mixin-based programming model
4. julia-mixins
   - a set of mixins implementing the default execution semantics
   - other mixins may be provided for other execution semantics

- (slight) mismatch around the term Julia
  - framework: julia-runtime + julia-asm
  - default execution semantics: julia-mixins
2.1 Julia

Control membrane programming

- **membrane descriptor**
  - text file(s) (e.g. julia.cfg) loaded by the framework which configures
    - control interfaces
    - controller implementations (set of mixins)
    - interceptor
    - optimization level
  
  for each membrane type (primitive, composite, etc.)

- **mixin-based programming model**
  - [Bracha, OOPSLA 1990]
  - replacement for multiple inheritance
  - foster reuse when developing controllers
  - enable optimizations
2.1 Julia

Intra-component optimization

- optimize memory footprint for a component
- various merge levels
  - controller (left-side)
  - + interceptors
  - + content
2.1 Julia

Inter-components optimization

- optimize runtime overhead
- compute shortcuts when several bindings are defined
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2.2 AOKell

- implementation of the Fractal Specifications
- aspect-based framework for engineering the control level

Expected benefits
- easier to develop, debug, maintain new controllers
- better integration with IDEs
- reducing the development time for writing new controllers
- reducing the learning curve
2.2 AOKell

AOKell: a contribution for opening the Fractal CF  [CBSE 2006]

- Existing controllers (technical services) in the Fractal CF
  - binding
  - attribute
  - lifecycle
  - content, super
  - name
  - component interfaces & type
  - template

- 1 AspectJ aspect per controller
  - glues the control dimension with the application dimension
  - delegates to the controller implementation
2.2 AOKell

The implementation of the control can benefit from components too
2.2 AOKell

- control component
  regular Fractal component providing a non functional property for an application level component

- membranes as assemblies of control components

- aspects to glue control components with application level components
  - code advising
  - code introduction
Instantiating a component
- creating the content
- instantiating the composite control component
- gluing them together with aspects (one per control component)

Issues: controlling the control components?
- control component control themselves (meta-circularity)?
- ad-hoc implementation of the (meta)-control ⇒ chosen solution

Conclusion
- uniform approach (ADL + comp.) for business and technical layers

Future work
- complex form of control architectures which span different components
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Fractal component model

- introspectable, dynamic
- fine-grained component (close to a class)
  - hierarchical approach to foster decomposition into sub-systems
- programming language independent
- structuring applications
  - at design & implementation time
  - at runtime
- tooling (Eclipse F4E, FractalExplorer, etc.)
3. Conclusion

Fractal component model

Many other tools/work not addressed by this presentation

- remote communication (Fractal RMI)
- administration (Fractal JMX)
- Think/Cecilia & embedded systems
- component libraries
  - DREAM, CLIF, Speedo, Perseus, GoTM, …
- binding factory
- compiling Fractal applications (Juliac)

- large ecosystem
3. Conclusion
3. Conclusion

- **R&D activities and Tools**
  - Formal models and calculi (INRIA, Verimag)
  - Configuration (Fractal/Think ADL - FT, INRIA, STM), navigation/query (EMN, FT)
  - Dynamic reconfiguration (FT, INRIA)
  - Management - Fractal JMX (FT)
  - Packaging, deployment (INRIA, LSR, Valoria)
  - Security, isolation (FT)
  - Correctness: structural integrity (FT), behavioural contracts based on assertions (ConFract - I3S, FT), behavior protocols (Charles U., FT), temporal logic (Fractal TLO - FT), automata (INRIA), test (Valoria)
  - QoS management (Plasma - INRIA, Qinna - FT)
  - Self-adaptation, autonomic computing (Jade - INRIA, Safran - EMN, FT)
  - Components & aspects (FAC, Julius, AOKell - INRIA, FT)
  - Components & transactions (Jironde - INRIA)

- **Some operational usages**
  - Jonathan, Jabyce, Dream, Perseus, Speedo, JOnAS (persistence), GoTM, CLIF…

- **Dissemination in industry (FT, STM, Nokia), universities including teaching (Grenoble, Chambéry, Nantes…), conferences (JC, LMO, SC, Euromicro…)**
3. Conclusion


Fractal Specifications
E. Bruneton, T. Coupaye, J.-B. Stefani.
The Fractal Component Model.
http://fractal.ow2.org/specification/index.html

Fractal & Julia
The Fractal Component Model and its Support in Java.

AOKell
L. Seinturier, N. Pessemier, L. Duchien, T. Coupaye.
A Component Model Engineered with Components and Aspects.
9th Intl. Symp. on Component-Based Software Engineering (CBSE).

Component Based Software Development
C. Szyperski.
Component Software – Beyond Object-Oriented Programming.
Thank you for your attention

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Questions?