Composition of Engineering Web Services

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Agenda

- Ubiquitous Computing Environment
- Service Integration – FICAS
Ubiquitous Computing Environment
Ubiquitous Computing – An AEC Scenario

- 3D/4D Modeling Tool Set
- Project Planning Tool Set
- On-Line Information Store

On Site Personnel → On-Line Information Store → Project Managers

Designers

Stanford University
Distributed Engineering Service and Integration

Mediators (Content and Access)
Information Exchange (DBMS, PSL, IFC, XML)
Service Integration (FICAS)

Engineering Application Services
An Integrated Service Environment

Ubiquitous Access

Communication Network

Integrated Work Processes

Data Integration Mobile Classes

Data Integration

Service Integration

Autonomous Service Wrapper

3D/4D Modeling Tools

Project Planning Tools

Supply Chain Tools

Designers

On Site Personnel

Project Managers
Ubiquitous Computing Environment – Three Issues

- Ubiquitous Access
  - Wireless Network Infrastructure
  - Wireless Devices
  - Device-independent Software Services

- Data Integration

- Service Integration
Supporting Multiple Devices Via Active Mediator

- Workstation
- Laptop
- PDA

Messaging Bus / Internet

Active Mediator

XML Objects
XML Style Sheet

Object Constructor

Source Information Services

Information Client
- Active Object Query
- Client-Specific Content

Information Abstraction

Source Query
Source Content

Information Content
Active Mediator in Action

- Mobile Class Fetcher
- Information Client
- Exception Handling
- Mobile Class Runtime
- Mobile Class Cache
- Result Object
- Source Object
- Data Mediator
- Object Constructor
- Source Information Services

Request + Mobile Class

Queries

Mobile Class

Active Mediator
Using PSL As Standard Exchange Language

- Primavera P3
- Vite

PSL Wrapper

PSL

PSL Wrapper

Translator

Database (Oracle 8i)

PSL Wrapper

PSL Wrapper

MS Project

4D Viewer
Using FICAS For Service Integration

CLAS Program

FICAS Buildtime

Megaservice Controller

Communication Network

Autonomous Service Directory

Autonomous Service Mediator

Software Application

FICAS Buildtime

FICAS Runtime
FICAS
(Flow-based Infrastructure for Composing Autonomous Services)
Service Composition

Megaservice Controller

Conceptual Composition of Autonomous Services

Physical Communication Backbone

Autonomous Service A

Access Protocol

Operating System A

Host A

Autonomous Service B

Access Protocol

Operating System B

Host B

Autonomous Service N

Access Protocol

Operating System N

Host N

Integration

Coding

1970 1990 2010
Service Composition Infrastructure

• **A Method to Integrate Software Applications**
  – A access protocol for desired software functionalities
  – ASAP (Autonomous Service Access Protocol)

• **A Method to Specify Functionality**
  – A compositional language
  – CLAS (Compositional Language for Autonomous Services)

• **An Environment to Execute Composed Services**
  – A runtime environment that coordinates control-flows and data-flows
  – FICAS (Flow-based Infrastructure for Composition Autonomous Services)
ASAP
(Autonomous Service Access Protocol)
Autonomous Service Metamodel

• **Service Core**
  – Represents the core service functionality
  – Wraps an existing software application

• **Data Containers**
  – Handle input and output data
  – Form data-flows
  – Enable distributed data-flows

• **Event Queues**
  – Handle inquiries and issue requests
  – Form control-flows
  – Enable asynchronous service invocations
Autonomous Service Access Protocol (ASAP)

• **ASAP**
  – A light-weight, asynchronous and non-blocking event-based protocol
  – Defines how autonomous services respond to events
  – XML is used as transport medium for both control and data

• **ASAP Events**
  – **SETUP, TERMINATE**: Initialization / termination of autonomous services
  – **INVOKE**: Invocation of autonomous services
  – **MAPDATA**: Management of data-flow between autonomous services
  – **CONTROLFILE**: Execution of megaservice control files
Autonomous Service Wrapper (ASW)

- **Purposes of ASW**
  - Facilitate wrapping of software applications into autonomous services
  - Implement data containers and event queues
  - Implement ASAP protocol

```java
public interface ServiceCore {
    public boolean setup(
        Container inc,
        Container outc,
        FlowId inf);

    public boolean execute(
        Container inc,
        Container outc,
        FlowId inf);

    public boolean terminate(
        Container inc,
        Container outc,
        FlowId inf);
}
```
CLAS
(Compositional Language for Autonomous Services)
CLAS

• **Compositional Language for Autonomous Services**
  – A high-level declarative language
  – Based on CLAM language developed in CHAIMS
  – Simple (Intended for domain experts, NOT technical experts)
  – Separation between composition and computation

• **Features**
  – Decomposition of a CALL statement into 4 primitives
    • SETUP, INVOKE, EXTRACT, TERMINATE
  – Control primitives
    • IF … THEN … ELSE
    • WHILE
  – Mobile class
    • For specifying computational logic
Mobile Class for Specifying Computational Logic

- **Mobile Class**
  - Java based
  - Dynamic routines that performs complex computational logic
  - Reusable

- **Example of Mobile Class**
  - Relational operators
    \[ \sigma_{\text{cond}}(A), \pi_{\text{attr}}(A), A \succ c \text{ cond} B \]
  - Arithmetic operators
    \[ +, -, \times, / \]
  - Data aggregation and abstraction
  - Type conversions

```java
/* Specification of a type conversion mobile class */
public class int2float implements MobileClass {
    public DataElement execute(Vector params) {
        DataElement arg =
            (DataElement) params.firstElement();
        int val = arg.getIntValue();
        return new DataElement().setValue(
            new Double(val).doubleValue());
    }
}

/* Using m-class in a CLAS program */
floatnum = MCLASS("int2float", num)
```
FICAS Buildtime

Source

CLAS Programs

Mobile Class Source Codes

Compilation

CLAS Compiler

Java Compiler

Executable

FICAS Controls

Mobile Classes

Compositional Specification

Computational Specification
Sample CLAS Program 1

SchedulingDemo "http://ficas.stanford.edu/Megaprogram"
{
    /* Setup Services */
    psl_svc = SETUP("SIPsl")
    p3_svc = SETUP("SIP3")
    notification_svc = SETUP("SINotification")

    /* Invoke and extract information from PSL Service */
    psl = psl_svc.INVOKE("to-psl", "CEIL")
    ceil = psl.EXTRACT()

    /* Invoke Rescheduling Service */
    p3 = p3_svc.INVOKE("reschedule", ceil)
    ceil2 = p3.EXTRACT()

    /* Store information using PSL Service */
    oracle = psl_svc.INVOKE("to-oracle", ceil2)
    status = oracle.EXTRACT()

    /* Invoke Notification Service */
   notif = notification_svc.INVOKE("171.64.55.32", 8250, status)

    /* Terminate Services */
    psl_svc.TERMINATE()
    p3_svc.TERMINATE()
    notification_svc.TERMINATE()
}
FICAS Runtime
FICAS Runtime Architecture

- **FICAS Controls**
- **Mobile Classes**
- **Communication Network**
- **Megaservice Controller**
- **Autonomous Service Wrapper**
- **Service Core**
- **Autonomous Service Directory**

From FICAS Buildtime
**Megaservice Controller**

---

**FICAS Control Sequence**

```
......
<INVOCATIONHANDEL> Invocation1 </INVOCATIONHANDEL>
<SERVICEHANDEL> Service1 </SERVICEHANDEL>
</INVOCATION>
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</EXTRACT>
<INVOCATIONHANDEL> Invocation3 </INVOCATIONHANDEL>
<SERVICEHANDEL> Service3 </SERVICEHANDEL>
<VALUELIST>
  <VARIABLE> A </VARIABLE>
  <VARIABLE> B </VARIABLE>
</VALUELIST>
......
```
Service Integration Models

(a) Centralized Control-flow
Centralized Data-flow Model
(1C1D)

(b) Centralized Control-flow
Distributed Data-flow Model
(1CnD)

(c) Distributed Control-flow
Centralized Data-flow Model
(nC1D)

(d) Distributed Control-flow
Distributed Data-flow Model
(nCnD)
Data Dependencies within Megaservice

/* Megaservice specified in CLAS */
Invocation1 = Service1.INVOKE();
Invocation2 = Service2.INVOKE();
A = Invocation1.EXTRACT();
B = Invocation2.EXTRACT();

Invocation3 = Service3.INVOKE(A, B);
C = Invocation3.EXTRACT();

Invocation4 = Service4.INVOKE(C)
D = Invocation4.EXTRACT();
Event Dependency Graph – 1C1D

Service 1

Service 2

Service 3

Service 4

MegaService

INVOKE
(Service1)

MAPDATA
(A, Service1, Megaservice)

MAPDATA
(A, Megaservice, Service3)

INVOKE
(Service3)

MAPDATA
(C, Service3, Megaservice)

MAPDATA
(C, Megaservice, Service4)

INVOKE
(Service4)

MAPDATA
(B, Service2, Megaservice)

MAPDATA
(B, Megaservice, Service3)

MAPDATA
(D, Service4, Megaservice)
Event Dependency Graph – 1CnD

Service 1 ➔ MegaService ➔ Service 2 ➔ Service 3 ➔ Service 4

INVOKE (Service1)

MAPDATA (A, Service1, Service3)

INVOKE (Service2)

MAPDATA (B, Service2, Service3)

INVOKE (Service3)

MAPDATA (C, Service3, Service4)

INVOKE (Service4)

MAPDATA (D, Service4, Megaservice)
/* Megaservice specified in CLAS */
Invocation1 = Service1.INVOKE();
Invocation2 = Service2.INVOKE();
A = Invocation1.EXTRACT();
B = Invocation2.EXTRACT();
Invocation3 = Service3.INVOKE(A, B);
C = Invocation3.EXTRACT();
Invocation4 = Service4.INVOKE(C)
D = Invocation4.EXTRACT();
Performance Evaluation – Apache SOAP v.s. FICAS

ForwardingData
{  
a = S1(size)
S2(a)
}

SingleCall
{  
a = S1(size)
}

MegeService

Switch

S1 produces and returns a string value

S2 consumes a string

(LAN) in = 10 mbps; out = 10 mbps
(802.11b) in = 2 mbps; out = 0.5 mbps
Megaservice Performance on LAN Setting

- SOAP (Single Call)
- SOAP (Forwarding Data)
- FICAS (Forwarding Data)

SOAP incurs higher data-flow cost.
FICAS incurs higher control-flow cost.
Megaservice Performance on 802.11b Setting

- SOAP creates bottleneck on the megaservice communication link
- FICAS is little affected since data-flows are distributed
Using Active Mediation for Performance Optimization

Example: Type Conversion Using Broker Services versus Mobile Classes

(a) Type Brokers

(b) Type Mediation Mobile Classes

Executing Mobile Class on Active Mediator

Mobile Class Repository

Mobile Class Fetcher

Mobile Class Cache

Exception Handling

Mobile Class Runtime

Mobile Class API Library

Active Mediator

Input Data Container

Output Data Container

Autonomous Service Wrapper
A Megaservice with a Mobile Class

Invocation1 = S1.INVOKE(size)
A = Invocation1.EXTRACT()

B = MCLASS("FILTER", A)

Invocation2 = S2.INVOKE(B)
Performance Comparison for Mobile Class Placements

![Graph showing data volume vs. Megaservice Execution Time for Mobile Class on S1, Mobile Class on S2, and Utility Autonomous Service.](image)
## Distributed Component Models

<table>
<thead>
<tr>
<th></th>
<th>CORBA</th>
<th>SOAP (Web Service)</th>
<th>FICAS</th>
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<tbody>
<tr>
<td>Data Representation</td>
<td>CDR (Common Data Representation)</td>
<td>XML</td>
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<td>Language Paradigm</td>
<td>Method Call</td>
<td>Procedure Call</td>
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<td>Invocation Model</td>
<td>Client-Server</td>
<td>Client-Server</td>
<td>Client-Server Active Mediation</td>
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<td>Dataflow Model</td>
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<td>Distributed</td>
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<td>Synchronicity</td>
<td>Sync / Asynchronous</td>
<td>Synchronous</td>
<td>Sync / Asynchronous</td>
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<td>Transport Protocol</td>
<td>IIOP</td>
<td>HTTP, SMTP</td>
<td>TCP</td>
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<td>Remote Reference</td>
<td>Proxy Reference</td>
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<td>URL</td>
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<td>Service Description</td>
<td>CORBA IDL (Interface Description Language)</td>
<td>WSDL (Web Service Description Language)</td>
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<td>Locating Services</td>
<td>CORBA Naming Service</td>
<td>UDDI (Universal Description, Discovery and Integration)</td>
<td>Autonomous Service Directory</td>
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</tbody>
</table>
FICAS Summary

• **Objective**
  – Investigate revolutionary approach to large-scale software composition

• **Approach**
  – Develop and validate a distributed data-flow based service composition framework

• **Contributions**
  – Protocol (ASAP) support for constructing autonomous services
  – A high-level language (CLAS) that separates composition from computation
  – Performance optimization with data-flow distribution
  – Active mediation to extend the capability of the compositional language and to facilitate data-flow optimization
Demonstration
Putting It All Together – Demonstration

Diagram showing the connections between various software tools and data formats, including:
- Palm
- Desktop Browser
- Primavera P3
- 4D Viewer
- Microsoft Project
- Microsoft Excel
- Active Mediator
- XML
- PSL
- Oracle 8i Relational Database
4D Model Taken on 3/25/2001 From 4DViewer
# Review Schedule in Primavera

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Activity Description</th>
<th>Orig Dur</th>
<th>Early Start</th>
<th>Early Finish</th>
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<td>18T1-32101</td>
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<td><strong>Form/Rebar/Pour SOMD 2nd Lift</strong></td>
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<td>08MY01</td>
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<td>01FEB01</td>
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# Review Schedule in Microsoft Project

<table>
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<th>Duration</th>
<th>Start</th>
<th>Finish</th>
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<td>Wed 1/31/01</td>
<td>Tue 6/5/01</td>
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View Schedule on Site

Review the schedule and make appropriate updates by changing the value in duration:

SCHEDULE

SCHEDULEID
STARTDATE
DURATION

18T1-33201
01-31-2001
1…………………….. Update

18T1-33241
02-01-2001
Modifying Schedule On-site

Review the schedule and make appropriate updates by changing the value in duration:

<table>
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<th>SCHEDULEID</th>
<th>STARTDATE</th>
<th>DURATION</th>
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Change duration of activity 18T1-33201 ("Erect Roof Elem 1") from 1 day to 40 days

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Invoke Rescheduling Megaservice

```
RescheduleService {
    model = PSLModel(modelname, 'oracle-to-psl')
    new_model = P3Scheduling(model, 'reschedule')
    PSLModel(new_model, 'psl-to-oracle')
    ExcelService(new_model, 'show')
    ChangeNotify(modelname)
}
```
### Review Modified Schedule in Primavera

#### FRP Slab on Metal Deck
- **ID:** 18T1-32101
- **Description:** FRP SMD 1st Lift T 1-3, Seq 22-24 Elem1
- **Orig Dur:** 12
- **Early Start:** 01JUN01
- **Early Finish:** 16JUL01
- **Status:**
  - F/RP SMD 1st Lift T 1-3, Seq 22-24 Elem1

#### Cure Concrete
- **ID:** 18T1-32102
- **Description:** CureConcrete RoofT 1-3 Seq 22-24 Elem1
- **Orig Dur:** 14
- **Early Start:** 17JUL01
- **Early Finish:** 30JUL01
- **Status:**
  - CureConcrete RoofT 1-3 Seq 22-24

#### Form/Rebar/Pour SMD 2nd Lift
- **ID:** 18T1-32331
- **Description:** F/RP SMD 2nd Li Roof, Seq 22-24, T1-3 Elem1
- **Status:**
  - FRP SMD 2nd Li Roof, Seq 22-24, T1-3 Elem1

#### Erect Secondary/Floor Frmng Steel
- **ID:** 18T1-33201
- **Description:** Erect Seq 22 T1 - Roof Elem1
- **Status:**
  - Erect Seq 22 T1 - Roof Elem1

#### Plum & Align Ceiling Steel
- **ID:** 17T1-33221
- **Description:** Erect Top/Bot Frmg T 1 Lvl 7 Elem1
- **Status:**
  - Erect Top/Bot Frmg T 1 Lvl 7 Elem1
Review Modified Design in 4D Viewer

4D Model Taken at 3/25/2001 From 4DViewer
Review Modified Schedule in Microsoft Project
Review Changed Activities in Desktop Browser

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