Integration of Web-Services and Agent Technology

A Service-Oriented Architecture-based Automation Framework

Dr.-Ing. Armando Walter Colombo
Overview

- Introduction and Motivation

- Collaborative Agent-based Automation and SoA Main Concepts

- The EU FP6 STREP InLife Approach
  The SoA Use-case

- The EU FP6 IP SOCRADES
  Merging SoA and Agent Technologies

- Conclusions and Outlooks
Motivation / Scientific and Technological Trends
From Rigid Coupling towards Dynamic Reconfigurable Production

- Mass Production
- Mass Customization

Trends in Production:

Approach: A New Generation of Intelligent Automation Systems

Too expensive, too slow to re-design and re-program automation and control systems for a new manufacturing system
Motivation/ Requirements from Customers
From rigid coupling towards dynamic reconfigurable production

Reconfigurability in real-time production conditions

- Plug-out / plug-in
- Plug and Produce/work
- Etc.
Motivation/ Requirements from Customers

Modular interoperable / interconnectable production components

Modularity of HW reflected into Modularity of Control and Automation Systems

- Plug-out / plug-in with different degrees of granularity
- Exchange/Integration of Mechatronics Modules (including Intelligent Control and Communication)
- The Embedded Component (TEC) into The Embedded Machine (TEM) into The Embedded Production System (TES)
Motivation/ Requirements from Customers
Flexible behaviour under real-time production conditions

Flexible material flow
- Chaotic flow of pallets
- Dynamic Re-scheduling to meet extrem customized production
- Short-term (local) decision-making capabilities
- Recover from un-expected situations in real-time production conditions
Motivation/ Requirements from Customers

Networking distributed modular components

- Traditional build is largely sequential with a major bottleneck during commissioning
  - Late application verification

- Pre-designed Modules can be rapidly built with minimum engineering effort and risk
  - Fast Ramp-up
  - Lower Costs
  - Easier Project management

Motivation/ Requirements from Customers

Networking distributed modular components

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  - Late application verification

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Source: Ford / University Loughborough
Collaborative Automation and Service Oriented Architectures
Towards complete decentralized and flat SoA- and Agent-based automation

Addressing customer values: Applications with SoA and WS
- Decentralised, non-hierarchical, flat application
- No gateway, no specific interface
- Uniform communication protocols
- Vertical and horizontal communication
- Peer-to-peer asynchronous communication
- High level, self-describing real-time protocols

Addressing customer values: Reconfigurability / Flexibility
- Dynamically add new devices, functions, machines.
- Duplicate machines or manufacturing lines “copy and paste” in Intelligent Devices
- Automatically build the application by assembling mechatronic devices (e.g. conveyors)
- Full Plug and Play/Run at the application level
- Detect and manage manufactured pieces of equipment
Collaborative Agent-based Automation and Service Oriented Architectures

What is a Service? – Link to a Physical Agent?

Build a system meeting given structural and behavioural requirements, from a given set of components, encompassing Heterogeneity and achieving Constructivity

Source: ARTEMISIA Conf. June 2007
Collaborative Agent-based Automation and Service Oriented Architectures

InLife: Componentization Concept / Building Blocks

<table>
<thead>
<tr>
<th>Each device is provided an IT frontend</th>
<th>Coalition Leader Service (CLS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Harmonizes the devices with the infrastructure</td>
<td>1. Orchestration</td>
</tr>
<tr>
<td>2. Improves Flexibility and Scalability</td>
<td>2. Aggregation</td>
</tr>
<tr>
<td>3. Enables (re)composition of the system using building blocks</td>
<td>3. Manufacturing Device Service (MDS)</td>
</tr>
<tr>
<td>4. Encapsulates complexity</td>
<td>4. IT Frontend for Manufacturing Devices</td>
</tr>
<tr>
<td></td>
<td>5. Service to Machine Interface (SMI)</td>
</tr>
<tr>
<td></td>
<td>5. Legacy Integration</td>
</tr>
<tr>
<td></td>
<td>6. Interoperability</td>
</tr>
</tbody>
</table>

**Implementation**

- Each type of service (CLS, MDS and SMI) is generic for a given family of hardware.
- Each service provides generic processing and information flow.
- Each service has a typical interaction pattern.

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Collaborative Agent-based Automation and Service Oriented Architectures

InLife: Componentization of a Flexible Assembly Cell (NOVAFLEX)

<table>
<thead>
<tr>
<th>Type of Service</th>
<th>Hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLS</td>
<td>Pallets, Station “Orchestrators”, Node “Orchestrators”</td>
</tr>
<tr>
<td>MDS</td>
<td>Robots, Grippers, Tool warehouses, Conveyors, Conveyors, Routing Devices, Fixing Devices</td>
</tr>
<tr>
<td>SMI</td>
<td>Bosch Controller SMI</td>
</tr>
</tbody>
</table>
### Collaborative Agent-based Automation and Service Oriented Architectures

**InLife: Architecture – Skills available in NOVAFLEX’s generic services**

<table>
<thead>
<tr>
<th>Type of Service</th>
<th>Device</th>
<th>Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SMI</strong></td>
<td>Bosch Station</td>
<td>“Interop” service</td>
</tr>
<tr>
<td><strong>MDS</strong></td>
<td>Gripper</td>
<td>grip, ungrip, get_lcp_list, get_lcp_item</td>
</tr>
<tr>
<td></td>
<td>Robot</td>
<td>move, move linear, change speed, lockgripper, unlockgripper</td>
</tr>
<tr>
<td></td>
<td>Tool Warehouse</td>
<td>store part, unstore part, get position to store part, get part position, confirm store, confirm unstore</td>
</tr>
<tr>
<td></td>
<td>Conveyor</td>
<td>input part, output part</td>
</tr>
<tr>
<td></td>
<td>Fixing Device</td>
<td>Fix pallet, unfix pallet</td>
</tr>
<tr>
<td><strong>Routing Device</strong></td>
<td></td>
<td>Output part</td>
</tr>
<tr>
<td><strong>CLS</strong></td>
<td>Coalition dependent</td>
<td>RobotMDS + gripperMDS -&gt; Pick and Place</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RobotMDS + gripperMDS + Tool Warehouse -&gt; Switch Gripper</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ConveyorMDS + RobotMDS + gripperMDS + Tool Warehouse -&gt; produce watch</td>
</tr>
<tr>
<td></td>
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<td>...</td>
</tr>
</tbody>
</table>
The pallet is the main Coalition Leader and orchestrates its way around the system.

Each station has its own orchestrator (CLS) that according to the devices under the coalition offers different complex skills. For instance Station 2 provides pick and place and switch gripper operations under the presence of the following MDS: robot, gripper and toolwarehouse.
Collaborative Agent-based Automation and Service Oriented Architectures

InLife: Use Case SoA / Test Scenario Demonstrator

- The full demonstration comprises 35 DPWS services
The EU FP6 IP SOCRADES
Service-Oriented Cross-Layer Infrastructures for Distributed Smart Embedded Devices

SOCRADES presents an unprecedented constellation of major European ICT players / stakeholders of the industrial value-chain (Co-ordinated by SE)

- 3-years Integrated Project (01.09.2006-31.08.2009)
- 15 Partners from 6 European Countries
- Efforts: 1100 PM
- Total Budget: 13.746.808 [Euro]

Web Page: www.socrades.eu
Integration of Web-Services and Agent Technology into SoA-based Automation

The EU FP6 IP SOCRADES
An Approach towards a Cross-Layer Reconfigurable Factory
The EU FP6 IP SOCRADES
A Cross-Layer Architecture

ERP/MES  Orchestr. \_i  Orchestr. \_j  Engineering System

IP network (wireline or wireless)

WS  WS  WS  WS  WS  WS

Device  Distr. IO  PLC, RC  Workpieces  Service mediator  Gateway

WS  WS  WS  WS  WS  WS

Workstations

WS  WS  WS  WS

Wireless Sensor / Actuator Network  Legacy & Low Resource Devices

E.g., Electronics Assembly Scenario

Dr. Armando Walter Colombo
Schneider Electric, BU Automation
September 29th, 2008, Stuttgart
Collaborative Automation and Service Oriented Architectures
A Production Component: Operational Modes & Services
Collaborative Automation and Service Oriented Architectures

A Production Component: Behaviour, Production-Flow & Services/Agent-based Decision
Collaborative Automation and Service Oriented Architectures

A SOCRADES Compliant Production Component
Collaborative Automation and Service Oriented Architectures in the Industry

The Shop Floor under the SOCRADES Architecture View
Collaborative Automation and Service Oriented Architectures

The SoA Architecture applied to the Assembly System Scenario

- Some Services are composed, e.g. according to physical structure
- Engines are integrated in device’s controllers
- Coordination through engine configured / programmed via IEC script or Petri Net
- Composite Services are hosted by device

Dr. Armando Walter Colombo
Schneider Electric, BU Automation
September 29th, 2008, Stuttgart
**AS-IS:** Standard (SE Unity) PLC system with remote IO

**TO-BE:** Fully distributed, embedded open control with *no* central PLC

Qualitative and quantitative evaluation against Ford’s future requirements
Embedded Web services are described using **ontology** in order to enable automatic discovery, selection, composition and invocation.

Embedded Web services can be **orchestrated** in order to create composite services.

Embedded Web services can be **managed**: dynamically deployed, (re)configured, etc.

Agents **discover** and **select** the Web services in order to execute the underlying physical processes. Then, the agents **invoke** the Web services in order to execute the underlying physical processes.

**SOCRADES**

**A SoA-based Production System: Behaviour**

Building block of the SOCRADIES infrastructure: service-oriented devices

Agents **discover** and **select** embedded Web services through **reasoning** processes. Then, the agents **invoke** the Web services in order to execute the underlying physical processes.

**Agent**

**WS Orchestration**

**WS Management** (Devs)

**WS Stack**

**Device**

**WS Device**

**WS Device**

**WS Device**

**WS Orchest.**

**Ontology**

(Semantic Web Service)

**Discovery, cognition**, selection, composition and invocation.

**Invocation**
Collaborative Automation and Service Oriented Architectures in the Industry

The Integration in the Cross-Layer Architecture
Collaborative Automation and Service Oriented Architectures in the Industry

Services: Prototype Implementations (R&D Agenda)

**Past:**
- Device
- Diagnostic Web Services
- Web Service on PC platform

**Today:**
- Devices
- Control
- Web server
- Ethernet
- Web Services In Gateway
- ETG prototype: COMAU, Prodatec

**Next:**
- Control + Communication Function/Service
- Web Service In Controller

**Vision:**
- Web Service Embedded in Controller
- Embedded in Mechanic
The 3 main messages


2. From the operational point of view, the services & physical agents are self-reliant production automation units, they are stable and able to survive disturbances. The subordination to higher level components ensures the effective operation of the larger whole within an enterprise architecture.

3. The results of the first SoA-based pilot installations at industrial level are very good and promising.

Acknowledgements

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Building
a New Electric World

Thanks for your attention!