Web Service Composition : Semantic Links based Approach

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- Dr. Biplav Srivastava: IBM’s T.J.Watson Research, Center in Hawthorne, NY, USA
- Dr. Bernd Amann: University Pierre and Marie Curie (LIP6), Paris, France.
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- Dr. Mohand-Saïd Hacid: University Claude Bernard (LIRIS), Lyon, France
- Pr. Olivier Boissier: École Nationale Supérieure des Mines, Saint-Etienne, France.
- Dr. Alexandre Delteil: Orange Labs, Issy, France.
- Dr. Alain Léger: Orange Labs, Rennes, France.
Web Service Composition

Motivation and Aim

As Web services proliferate:

- It becomes possible to compose them at hand;
- ... especially when there is no relevant single service;

Selecting and combining existing services, available on the Web, to provide added-value services featuring higher level functionalities.
Web Service Composition

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As Web services proliferate:
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- ... especially when there is no relevant single service;

Web Service Composition

Selecting and combining existing services, available on the Web, to provide added-value services featuring higher level functionalities.
Automated, Dynamic and Semantic Web Service Composition

Driving Idea

1. Automated
2. and Dynamic Web service composition
   - in the Semantic Web
   - and in Industrial settings.
Related Work

SWS Composition Planners

- Service execution at planning time (interleaving)
- No service execution at planning time

Reactive
- Any service
- Pure reactive, Contingency

Advanced
- Only info gathering services
- Replanning (changes)

Restricted
- Only info gathering services

Non-Classical
- Contingency
- Conformant

Classical
- Deterministic
- Complete Initial States

Planning under uncertainty
Web Service Composition

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Planning under uncertainty

Functional Description
- Pre-Conditions
- Post-Conditions
- Name
- Description
- Input Parameters
- Output Parameters

Behavioural Description
- Input/Output Message
Web Service Composition

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Planning under uncertainty

Process Level

- OWLS−XPlan2 (Klusch+, 06)
- SHOP2 (Sirin+, 02)
- OWLS−XPlan1 (Klusch+, 06)
- PLCP (Pistore+, 05)
- Optop (McDermott, 02)
- Roman Model (Berardi+, 05)
- Mealy Model (Hull+, 03)

Functional Level

- Automation
- Expressivity
- Composability
- Optimization
- Applicability

- WSPLan (Peer, 05)
- FFPanner (Hoffmann+, 07)
- Golog-SCP (McIlraith+, 02)
- Optop (McDermott, 02)

- MetaComp (Botelho+, 07)
- GOAL (Pfalzgraf, 06)
- Agora−SCP (Rao+, 06)
- SAWSDL−SCP (Wu+, 07)
- OntoMat−S (Agarwal+, 04)
- Mealy Model (Hull+, 03)
- SemaPlan (Akkiraju+, 06)
- Onto−Comp (Arpinar+, 05)
- IW−RTC (Agre+,07)

- FFPanner (Hoffmann+, 07)
- (Lassila, 04)
- Golog-SCP (McIlraith+, 02)
- Optop (McDermott, 02)
Objective

Context
- Web Service Composition at Functional Level.
- Sequential, *Conditional* and Concurrent compositions.

Thesis
- Semantic links between parameters of services
- with their extension to Causal laws
  → Key elements for:
    1. automated composition of stateless Web Services
    2. the optimisation of their candidate compositions.
Web Service Composition

What Kind of Services and Compositions?

Semantic Web Services at Functional Level

- **Stateless** Web services:
  - No Behaviour-aware Web services.
- **Input and Output** Parameters:
  - concepts in an ontology $T$.
- **Preconditions and Effects**:
  - properties on inputs and outputs.

Composition Constructs

- **Sequential**;
- **Non Determinism**;
- **Concurrency**.
Outline

1. Optimal Composition of Web Services with Semantic Links and Causal Laws
2. Web Services Composability
3. Automated Web Service Composition Approaches
4. Optimizing Web Service Composition (Process)
5. Validation and Experimentation

Summary

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General Overview

Composability

- **Semantic Links** and their Robustness;
- Causal Laws.

Composability

Complex relationship between facts (Propagation Information)

\[ \text{Service} \]

- **Precondition** \( S_y \)
- **Effect** \( S_y \)
- **Precondition** \( S_x \)
- **Effect** \( S_x \)

Semantic Matchmaking

Causality Relationship

\[ \text{In}_{S_y} \]
\[ \text{Out}_{S_y} \]
\[ \text{In}_{S_x} \]
\[ \text{Out}_{S_x} \]
Web Service Composition and its Semantic Links

- **Semantic Link**: Semantic connection between services;
  - ... more particularly between Output and Input parameters;
  - ... denoted by $s_{y,x}$ and valued by $\text{Sim}_{T}(\text{Out}_{-sy}, \text{In}_{-sx})$;

### Academic Contributions

- F. Lécué and A. Léger
  A formal model for semantic Web service composition

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  Semantic Web service composition based on a closed world assumption
  In *ECOWS*, pages 233-242, Zurich, Switzerland, December 2006.
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[M.Paolucci et al. ISWC’02, Li and Horrocks WWW’03]:

- **Exact** i.e., $T \models Out_{s_y} \equiv In_{s_x}$;
- **PlugIn** i.e., $T \models Out_{s_y} \sqsubseteq In_{s_x}$;
- **Subsume** i.e., $T \models In_{s_x} \sqsubseteq Out_{s_y}$;
- **Intersection** i.e., $T \not\models Out_{s_y} \cap In_{s_x} \sqsubseteq \bot$;
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**Web Service Composition and its Semantic Links**
Semantic Link: Semantic connection between services;
... more particularly between Output and Input parameters;
... denoted by $sl_{y,x}$ and valued by $Sim_T(Out_{sy}, In_{sx})$;

$Sim_T$ is reduced to the five matchmaking functions [M.Paolucci et al. ISWC’02, Li and Horrocks WWW’03]:
- **Exact** i.e., Robust;
- **PlugIn** i.e., Robust;
- **Subsume** i.e., Non Robust;
- **Intersection** i.e., Non Robust;
- **Disjoint**.
The open issue: How could we transform a non robust semantic link $\text{Sim}_T(Out_s y, In_s x)$ in its robust form?

The suggested approach: by retrieving information contained by $In_s x$ and not by $Out_s y$ through Concept Difference or Concept Abduction.

Academic Contributions

F. Lécué and A. Delteil
Making the Difference in Semantic Web Service Composition

F. Lécué and A. Delteil and A. Léger
Applying Abduction in Semantic Web Service Composition
In ICWS, pages 94-101, Salt Lake City, USA, July 2007.
Robust Semantic Links

Definition (Concept Difference)

The difference between two concept descriptions $\text{In}_{s_x}$ and $\text{Out}_{s_y}$ is given by

$$\text{In}_{s_x} \setminus \text{Out}_{s_y} := \min_{\leq d} \{H | H \cap \text{Out}_{s_y} \equiv \text{In}_{s_x} \cap \text{Out}_{s_y} \}$$
Robust Semantic Links

Definition (Concept Difference)

The difference between two concept descriptions $In_{s_x}$ and $Out_{s_y}$ is given by:

$$In_{s_x} \setminus Out_{s_y} := \min\{H|H \sqsubseteq dOut_{s_y} \equiv In_{s_x} \cap Out_{s_y}\}$$

- e.g., in case of non robust semantic link valued by the Subsume match level.

Web service: $s_y$

$S_y$ Output Parameters

$S_y$ Input Parameters

$S_x$ Input Parameters

$S_x$ Output Parameters

NetworkConnection $\equiv \forall netSpeed.Speed$

SlowNetworkConnection $\equiv NetworkConnection \sqcap \forall netSpeed.Adsl1M$

Web service: $s_x$
Robust Semantic Links

Definition (Concept Difference)

The difference between two concept descriptions $\text{In}_{sx}$ and $\text{Out}_{sy}$ is given by

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- e.g., in case of non robust semantic link valued by the Subsume match level.
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The difference between two concept descriptions $\text{In}_{sx}$ and $\text{Out}_{sy}$ is given by

$$\text{In}_{sx} \setminus \text{Out}_{sy} := \min_{d} \{ H \mid H \cap \text{Out}_{sy} \equiv \text{In}_{sx} \cap \text{Out}_{sy} \}$$

Driving Ideas

- Explain *Where*, *Why* a semantic link is not robust...
- ... hence a way to replace (How) a non robust semantic link in its robust form:
  - **Subsume** match level $\Rightarrow$ **Exact** match level;
  - **Intersection** match level $\Rightarrow$ **PlugIn** match level.
Causal Law Definition

In a Nutshell

- Initially from the **AI planning area**:
  - i.e., causality relationships between effects, preconditions;
  - here adding expressivity to semantic links.

- relationships that link an input parameter of a service to an output parameter of another service under some conditions.

Causal Law (Information propagation between AdslEligibility, VoiceOverIP)

Academic Contribution

F. Lécué and A. Delteil and A. Léger
DL Reasoning and AI Planning for Web Service Composition
Outline

1. Optimal Composition of Web Services with Semantic Links and Causal Laws
   - ISWC'06, ECOWS'06, Robustness AAAI'07, ICWS'07

2. Web Services Composability

3. Automated Web Service Composition Approaches

4. Optimizing Web Service Composition (Process)

5. Validation and Experimentation

Summary

1. Semantic Links ISWC'06, ECOWS'06, Robustness AAAI'07, ICWS'07
2. Causal Laws WI'08
Outline

1. Optimal Composition of Web Services with Semantic Links and Causal Laws
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Semantic Link based Composition

Semantic Link Matrix SLM (1)

Our Proposal
- An appropriate and innovative **formal** model:
  - used as a **starting point** for the automation of WSC;
  - that improves the way to store semantic links;
  - that **eases** Web service **composition** and **selection**;
  - ... under **semantic composability** $s_x \circ s_y$ constraints;

Key Contribution of SLMs
- **controlling** a set of **relevant services** for composition;
- **pre-computing** all possible **interactions** ($s_x \circ s_y$).

Academic Contributions
F. Lécué and Olivier Boissier and Alexandre Delteil and A. Léger
Web Service Composition as a Composition of Valid and Robust Semantic Links
### In a Nutshell

Each entry $m_{i,j}$ of a SLM:
- a set of $(s_y, \text{score}) \in S_{Ws} \times (0, 1]$ with

$$(s_y, \text{score}) := (s_y, \text{Sim}_T(\text{Out}_s y, c_j))$$

### Details

$$\begin{pmatrix}
m_{1,1} & m_{1,2} & \cdots & \cdots & m_{1,q} \\
m_{2,1} & m_{2,2} & \cdots & \cdots & m_{2,q} \\
\vdots & \vdots & \ddots & \ddots & \vdots \\
m_{p,1} & m_{p,2} & \cdots & \cdots & m_{p,q}
\end{pmatrix}$$

### Semantic Link based Composition

#### Semantic Link Matrix SLM (2)

- Semantic Link Matrix $SLM$:
  - Each entry $m_{i,j}$ represents a set of $(s_y, \text{score})$.
  - $(s_y, \text{score}) := (s_y, \text{Sim}_T(\text{Out}_s y, c_j))$.

- Diagram illustrating the relationship between web services and concepts.

- $T\#Concept_j$ and $T\#Out_s y$ are connected through semantic links.

- Web service $S_y$ is connected to $T\#Concept_i$.
A Regression-based Approach

Requirements

- A TBox $\mathcal{T}$ to infer concepts Matching;
- An AI planning problem $\Pi = \langle S_{Ws}, A, \beta \rangle$;
  - $S_{Ws}$ i.e., a set of possible state transitions;
  - $A$ is the *Initial state* as an ABox.
  - $\beta \subseteq \mathcal{T}$ is an explicit goal representation.
- A SLM $\mathcal{M}$ and its semantic links;

Details

\[
\begin{array}{cccccccc}
\text{Email} & \text{Decoder} & \text{FastNC} & \text{IPAddress} & \text{PhoneNumber} & \text{SlowNC} & \text{ZipCode} & \text{Invoice} \\
0 & 0 & \{(S_a^-, \frac{1}{2}), (S_a, \frac{1}{2}), (S_a^+, 1)\} & 0 & 0 & \{(S_a^-, 1), (S_a, \frac{1}{2}), (S_a^+, \frac{3}{4})\} & 0 & 0 \\
0 & 0 & \{(S_c, \frac{3}{4})\} & 0 & 0 & \{(S_a^-, 1), (S_a, \frac{1}{2}), (S_a^+, \frac{3}{4})\} & 0 & 0 \\
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\end{array}
\]
Suppose a \( SLM \ M \) and \( \Pi = \langle S_{W_S}, A, \beta \rangle \);

By the \( SLM \) definition, \( S_{W_S}, A \) and \( \beta \) are referred by \( M \).

<table>
<thead>
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By the SLM definition, $S_{\text{WS}}$, $\mathcal{A}$ and $\beta$ are referred by $\mathcal{M}$.

The composition process: a recursive and regression-based approach;

From the goal $\text{In}$.
Example

- Suppose a $SLM \mathcal{M}$ and $\Pi = \langle S_{W_S}, A, \beta \rangle$;
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    0 & 0 & \{(S_a^-, \frac{1}{2}), (S_a^+, \frac{1}{2}), (S_a^+, 1)\} & 0 & 0 & \{(S_a^-, 1), (S_a^+, \frac{1}{2}), (S_a^+, \frac{3}{2})\} & 0 & 0
\end{pmatrix}
\]
Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{Ws}, A, \beta \rangle$;

By the SLM definition, $S_{Ws}$, $A$ and $\beta$ are referred by $\mathcal{M}$.

The composition process: a recursive and regression-based approach;

From the goal $In.$, the new goal $De.$
Suppose a $SLM\ M$ and $\Pi = \langle S_{WS}, A, \beta \rangle$;
By the $SLM$ definition, $S_{WS}$, $A$ and $\beta$ are referred by $M$.
Example

Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{WS}, A, \beta \rangle$;

By the SLM definition, $S_{WS}$, $A$ and $\beta$ are referred by $\mathcal{M}$.

The composition process: a recursive and regression-based approach;

- From the goal $In.$, the new goal $De.$

```
0 0 0 {(Sa, 1/2), (Sa, 1/2), (Sa+, 1)}
0 0 0 {(Sa+, 1/2), (Sa, 1/2), (Sa+, 1)}
0 0 0 {(Sc, 3/4)}
0 0 0 {(Sa+, 1/2), (Sa+, 1/2), (Sa+, 1)}
0 0 0 {(Sc, 3/4)}
0 0 0 {(Sa+, 1/2), (Sa+, 1/2), (Sa+, 1)}
```

```
(Sd, 1) (Sc, 3/4) (Sc, 3/4)
```

```
(Sd, 1) (Sd, 1)
```
### Semantic Link based Composition

#### Example

- Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{Ws}, A, \beta \rangle$;
- By the SLM definition, $S_{Ws}$, $A$ and $\beta$ are referred by $\mathcal{M}$.

**Table: SLM Example**

<table>
<thead>
<tr>
<th>Email</th>
<th>Decoder</th>
<th>FastNC</th>
<th>IP Address</th>
<th>Phone Num</th>
<th>SlowNC</th>
<th>Zip Code</th>
<th>Invoice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email</td>
<td>Decoder</td>
<td>$(S_a^-, 1/2), (S_a^-, 1), (S_a^+, 1)$</td>
<td>$S_a^-$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
</tr>
<tr>
<td>Decoder</td>
<td>FastNC</td>
<td>$S_a^-$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
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<td>$S_a^- \times 1$</td>
</tr>
<tr>
<td>FastNC</td>
<td>IP Address</td>
<td>$(S_a^-, 1/2), (S_a^-, 1), (S_a^+, 1)$</td>
<td>$S_a^-$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
</tr>
<tr>
<td>IP Address</td>
<td>Phone Num</td>
<td>$(S_b, 1/4)$</td>
<td>$S_b^-$</td>
<td>$S_b^- \times 1$</td>
<td>$S_b^- \times 1$</td>
<td>$S_b^- \times 1$</td>
<td>$S_b^- \times 1$</td>
</tr>
<tr>
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<td>SlowNC</td>
<td>$(S_a^-, 1/2), (S_a^-, 1), (S_a^+, 1)$</td>
<td>$S_a^-$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
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<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
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<td>Invoice</td>
<td>$(S_a^-, 1/2), (S_a^-, 1), (S_a^+, 1)$</td>
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<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
<td>$S_a^- \times 1$</td>
</tr>
</tbody>
</table>

- The composition process: a recursive and regression-based approach;
- From the goal $In., De.,$ the new goal $Fa.$

![Diagram](attachment://composition_process.png)
### Semantic Link based Composition

#### Example

- Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{W_S}, A, \beta \rangle$;
- By the SLM definition, $S_{W_S}$, $A$ and $\beta$ are referred by $\mathcal{M}$.

<table>
<thead>
<tr>
<th>Email</th>
<th>Decoder</th>
<th>FastNC</th>
<th>IP Address</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Email</td>
<td>Decoder</td>
<td>FastNC</td>
<td>IP Address</td>
<td>Phone Num</td>
<td>SlowNC</td>
<td>Zip Code</td>
<td>Invoice</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>${ (S_b^-, 1), (S_b^+, 1) }$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>${ (S_c^-, 3/4) }$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>${ (S_c^-, 3/4) }$</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>${ (S_c^-, 3/4) }$</td>
<td>0</td>
<td>0</td>
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</tr>
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</table>

- The composition process: a recursive and regression-based approach;
- From the goal $\text{In.}$, $\text{De.}$, the new goal $\text{Fa.}$.
Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{WS}, A, \beta \rangle$;

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The composition process: a recursive and regression-based approach;

From the goal In., De., the new goal $Fa$. 

Details
Causal Law based Composition

Motivation

- **Enriching and extending the composition model** with:
  - Further **Expressivity on semantic links and services**;
  - **Relationships between facts** in Web service composition.
  - Further **Composability criteria**.

Academic Contribution

F. Lécué and A. Delteil and A. Léger
DL Reasoning and AI Planning for Web Service Composition
Causal Law based Composition

In a Nutshell (1)

Context

- **Services** as *(conditional)* sGolog actions;
- Semantic links axioms *(Extended in any situation)*;
- Causal laws as Successor States axioms.

Solution: Extension of the Pure Semantic Link based Model

- Extension of sGolog with **conditional** actions/compositions.

Academic Contribution

F. Lécué and A. Delteil and A. Léger
DL Reasoning and AI Planning for Web Service Composition
In a Nutshell (2)

DL Description of the Domain

DL Knowledge Base (Ontology)
ABox, TBox

Semantic Web Services in DL
Causal Law based Composition

In a Nutshell (2)

DL Description of the Domain

- DL Knowledge Base (Ontology)
- Semantic Web Services in DL

Situation Calculus Description of the Domain

- Actions in Situation Calculus
  - $\Sigma$
  - $D_{ap}$
  - $D_{una}$
  - $D_{S0}$
  - $D_{ss}$
  - $D_{sr}$
Causal Law based Composition

In a Nutshell (2)

DL Description of the Domain

- DL Knowledge Base (Ontology)
  - ABox, TBox
- Reasoning on TBox (e.g., Satisfiability, Subsumption)
- Semantic Web Services in DL
- Reasoning on ABox (e.g., Instance Checking)
- Instance($X, x$)

Situation Calculus Description of the Domain

- Actions in Situation Calculus
  - $\Sigma$
  - $D_{una}$
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  - $D_{ss}$
  - $D_{sr}$

DL Reasoning

Semantic Links
Causal Law based Composition

In a Nutshell (2)

**DL Description of the Domain**
- **DL Knowledge Base** (Ontology)
- **ABox**
- **TBox**

**Reasoning on TBox** (e.g., Satisfiability, Subsumption)

**Semantic Web Services in DL**

**Reasoning on ABox** (e.g., Instance Checking)

**Instance** \((X, x)\)

**DL Reasoning**

**Situation Calculus Description of the Domain**

- **Actions in Situation Calculus**
- **\(\Sigma\)**
- **\(\mathcal{D}_V\)**
- **\(\mathcal{D}_{op}\)**
- **\(\mathcal{D}_{una}\)**
- **\(\mathcal{D}_{S_0}\)**
- **\(\mathcal{D}_{ss}\)**
- **\(\mathcal{D}_{sr}\)**

**Semantic Links**
In a Nutshell (2)

DL Description of the Domain

- DL Knowledge Base (Ontology)
  - ABox
  - TBox

- Reasoning on TBox (e.g., Satisfiability, Subsumption)

- Reasoning on ABox (e.g., Instance Checking)

Situation Calculus Description of the Domain

- Actions in Situation Calculus
  - \( \Sigma \)
  - \( D_{una} \)
  - \( D_V \)
  - \( D_{ap} \)
  - \( D_{S0} \)
  - \( D_{ss} \)
  - \( D_{sr} \)

- Semantic Links

DL Reasoning

Composition

Backward Chaining based AI Planning (Golog Reasoning)

\[ \Sigma \cup D_{una} \cup D_{ap} \cup D_{S0} \cup D_{ss} \cup D_{sr} \cup D_V \models (\omega, S_0, g) \]
Causal Law based Composition

In a Nutshell (2)

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  - \( D_{V} \)
  - \( D_{ap} \)
  - \( D_{S0} \)
  - \( D_{ss} \)
  - \( D_{sr} \)

**Semantic Links**
- Semantic Web Services in DL

**DL Reasoning**
- Instance \( (X, x) \)

**Backward Chaining based AI Planning (Golog Reasoning)**

\[ \Sigma \cup D_{una} \cup D_{ap} \cup D_{S0} \cup D_{ss} \cup D_{sr} \cup D_{V} \models (\omega, S_0, g) \]
Causal Law based Composition

In a Nutshell (2)

- **DL Description of the Domain**
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  - Semantic Web Services in DL
  - Reasoning on TBox (e.g., Satisfiability, Subsumption)
  - Reasoning on ABox (e.g., Instance Checking)

- **Situation Calculus Description of the Domain**
  - Actions in Situation Calculus
  - Semantic Links

- **DL Reasoning**

- **On line Execution of the composition**
  - $g$, a conditional composition of Web services with semantic links and causal laws

- **Backward Chaining based AI Planning** (Golog Reasoning)
  - $\Sigma \cup \mathcal{D}_{una} \cup \mathcal{D}_{ap} \cup \mathcal{D}_{S0} \cup \mathcal{D}_{ss} \cup \mathcal{D}_{sr} \cup \mathcal{D}_V \models (\omega, S_0, g)$
Causal Law based Composition

Example

Required Axioms: $\Sigma, D_{una}, D_{v}$ and ...

$D_{s0}, D_{ss}, D_{sr}, D_{ap}$
Causal Law based Composition

Example

Required Axioms: $\Sigma, \mathcal{D}_{\text{un}a}, \mathcal{D}_V$ and ...

- $\mathcal{D}_{S_0}$, $\mathcal{D}_{ss}$, $\mathcal{D}_{sr}$, $\mathcal{D}_{ap}$,
- FrenchPhone(+33299124625, $S_0$);
- FrenchZip(35512, $S_0$);
- validMail(freddy.lecue@orange-ftgroup.com, $S_0$).
Required Axioms: $\Sigma$, $D_{una}$, $D_V$ and ...

$D_{S_0}$, $D_{ss}$, $D_{sr}$, $D_{ap}$,

$\text{phoneNumberOf(output(VoiceOverIP(x), 1), ph_nb, do(VoiceOverIP(x), s))} \leftarrow \text{Poss(VoiceOverIP(x), s)} \land (\text{phoneNumberOf(x, ph_nb, s)} \lor \text{phoneNumberOf(output(VoiceOverIP(x), 1), ph_nb, s)})$
### Example

**Causal Law based Composition**

**Required Axioms:** $\Sigma, \mathcal{D}_{una}, \mathcal{D}_v$ and ...

- $\mathcal{D}_{s0}$, $\mathcal{D}_{ss}$, $\mathcal{D}_{sr}$, $\mathcal{D}_{ap}$,

$$sr(\text{AdslEligibility}, s) \leftarrow \text{NetworkConnection}(x, s)$$
Causal Law based Composition

Example

Required Axioms: $\Sigma$, $D_{una}$, $D_V$ and ...

- $D_{S_0}$, $D_{ss}$, $D_{sr}$, $D_{ap}$,

$\text{Poss}(\text{VoiceOverIP}(x), s) \equiv$

$\text{validNetworkConnection}(x, s) \land$
$\text{supportConnectionType}(x, s) \land$
$KRef(\text{NetworkConnection}(x), s)$
Outline

1. Optimal Composition of Web Services with Semantic Links and Causal Laws
2. Web Services Composability
3. Automated Web Service Composition Approaches
4. Optimizing Web Service Composition (Process)
5. Validation and Experimentation

Summary

1. Semantic Link based Composition IJCIS’08
2. Causal Law based Composition WI’08
Outline

1. Optimal Composition of Web Services with Semantic Links and Causal Laws
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Optimizing Web Service Composition (Process)

Automated Web Service Composition Approaches

Web Services Composability

Optimal Composition of Web Services with Semantic Links and Causal Laws
Composition Result Modelling

Process Model as a Statechart
- Its states refer to services;
- Its transitions are labelled with semantic links;
- with basic composition constructs.

Legend
- Semantic Link
- Input Parameter
- Output Parameter
- T: Task
- s: Service
Quality Model

Semantic Link and Composition Quality Criteria

A Quality Vector for Semantic Link

\[ q(sl_{i,j}) = (q_r(sl_{i,j}), q_{cd}(sl_{i,j}), q_m(sl_{i,j})) \]

- robustness \( q_r \);
- common description rate \( q_{cd} \);
- matching Quality \( q_m \).

A Quality Vector for Semantic Link Composition

\[ Q(c) = (Q_r(c), Q_{cd}(c), Q_m(c)) \]

- Sequential, Concurrent and Conditional compositions.

Academic Contribution

F. Lécué and A. Delteil and A. Léger

Optimizing Causal Link based Web Service Composition

Global Optimal Composition (1)

Our Approach

- mapped into an integer linear programming (IP) problem.

Features

- Still $\text{Exp\_Time}$;
- vs. the naive approach (Exhaustive Search!).
  1. further constraining semantic links;
  2. meeting a given global objective.

Academic Contribution

F. Lécué and A. Delteil and A. Léger
Optimizing Causal Link based Web Service Composition
Global Optimal Composition (2)

Inputs of the IP Problem

- A (linear) *objective function*;
- *Integer variables* (restricted to 0 or 1);
- (linear) *constraints* (Allocation, Incompatibility, ...)

Objective Function

\[
\max_{1 \leq \lambda \leq p} \left( \sum_{l \in \{r,c,d,m\}} (\sim Q^\lambda_l \times \omega_l) \right)
\]
Global Optimal Composition (2)

Inputs of the IP Problem

- A (linear) **objective function**;
- **Integer variables** (restricted to 0 or 1);
- (linear) **constraints** (Allocation, Incompatibility, ...)

Legend
- **Candidate**
- **Abstract**
- **Semantic Link** $sl^A_{i,j}$
- **Integer Variable** $y^k_{i,j}$
- Input Parameter
- Output Parameter

T: Task
s: Candidate Service
Global Optimal Composition (2)

Inputs of the IP Problem

- A (linear) *objective function*;
- *Integer variables* (restricted to 0 or 1);
- (linear) *constraints* (*Allocation*, *Incompatibility*, ...)

Legend

- **Candidate**
- **Semantic Link** $sl_{i,j}^k$
- **Abstract**
- **Semantic Link** $cl_{i,j}^A$
- **Integer Variable** $y_{i,j}^k$
  - **Input Parameter**
  - **Output Parameter**

T: Task
s: Candidate Service
Global Optimal Composition (2)

Inputs of the IP Problem

- A (linear) *objective function*;
- *Integer variables* (restricted to 0 or 1);
- (linear) *constraints* (Allocation, Incompatibility, ...)

Outputs of the IP Problem

- The *maximum* (or minimum) value of the *objective function*;
- *Values of variables* at this maximum (minimum).
Outline

1. Optimal Composition of Web Services with Semantic Links and Causal Laws
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Summary

1. Generic approach ECAI’08 (Composition → IP problem);
2. Flexible model with other semantic criteria.
1. Optimal Composition of Web Services with Semantic Links and Causal Laws
2. Web Services Composability
3. Automated Web Service Composition Approaches
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The Reference Architecture

End User’s Request
Service Goal $s_g$

$s_g := (A, \beta)$

Repository of Semantic Web Services $S^*_W S$

Impl:jUDDI

Services Parsing

Service Discovery and Selection
Impl:Naive

Repository of Domain Ontology

Impl:Fact++

Semantics Reasoning

Causal Laws Reasoning
Impl:Golog Formalism

Impl:WSML

Not Found

Relevant Services

$S^*_W S$

Not Found

Candidate Compositions

Candidate Compositions

Impl:Golog

Impl:CPLEX

Services involved in Composition

Impl:java,perl-based

BPEL Rendering
Impl:Perl-based

Contributions

Academics

Industry
Motivation, Orientation and Validation

- Industrial settings (stateless Web services);

Industrial Transfer through Different Scenarios in

- France Telecom AgIS;
- European Project (FP6) SPICE;
- Network of excellence (FP6) Knowledge Web.
Industrial Scenarios in Use - An Example

Internet Package

- **Dynamic and automated configuration** of Web services.
  - 35 Web services;
  - ALE ontology (305 concepts, 117 properties).

Nowadays Solutions

- **Static/Predefined** packages.
  - ADSL Max+ + HDTV.

Open Issue

- How to customize commercial offers in a dynamic way?
- The more offers the harder the composition task will be.
Main Results for Composition (Scenarios-Dependence!)

- AI planning is more time consuming than DL reasoning.
- The optimization process takes a negligible time.

Best Practices for using our Approach

<table>
<thead>
<tr>
<th>Process</th>
<th>Parameters</th>
<th>Computation Time in ms</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>Semantic Links oriented</td>
<td>Nb services</td>
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<tr>
<td></td>
<td>Nb Inputs, Outputs</td>
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<td>Nb services</td>
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</tr>
<tr>
<td></td>
<td>Nb Candidate semantic Link</td>
<td>100</td>
</tr>
</tbody>
</table>
Outline

1. Optimal Composition of Web Services with Semantic Links and Causal Laws
2. Web Services Composability
3. Automated Web Service Composition Approaches
4. Optimizing Web Service Composition (Process)

Validation and Experimentation

Summary

1. A reference architecture ICWS’07, IJCIS’08;
2. Validation in Industrial settings NoE Knowledge Web, IST Spice, FT.
Contributions

1. Analysis of Requirements
   - Automation, Expressivity, Applicability, Composability, Optimization.

2. **SME³-Comp** (SeMantic wEb sErvicE) Software:
   - (Robust) Semantic Link, SLM and Causal Laws;
   - Automated Composition approaches;
   - Composition Optimization;

3. Achievement in practical and Industrial scenarios;

Lessons Learnt

- Exp_Time Problem!
- Composition’s Complexity Criteria:
  - Web Service Input/Output Expressivity, Cardinality;
  - Ontology Expressivity.
- Composition of thousand of services is not yet a reality.
Future Work

1. Adding **Semantics** on Links;
2. Investigating in **Expressiveness** of Web Services;
3. Exploring **Expressiveness** of Composition Constructs;
4. Automating **Robust Web Service Composition**;
5. Improving **Quality of Composition**:
   - Coupling Quality of **Service** and **Semantic Links**;
   - Coupling **Composition** and **Discovery**.
6. Investigating in further **Scenarios, Benchmarks** (**SWS Challenge**).
Perspectives

Future Work

1. Adding **Semantics** on Links;
2. Investigating in **Expressiveness** of Web Services;
3. Exploring **Expressiveness** of Composition Constructs;
4. Automating **Robust Web Service Composition**;
5. Improving **Quality of Composition**:
   - Coupling Quality of **Service** and **Semantic Links**;
   - Coupling **Composition** and **Discovery**.
6. Investigating in further **Scenarios, Benchmarks** (SWS Challenge).

Thanks for your attention!

Freddy Lécué
freddy.lecue@orange-ftgroup.com
Academic Contributions (1)

F. Lécué and Eduardo Silva and Luis Ferreira Pires
A Framework for Dynamic Web Services Composition
In *Emerging Web Services Technology 2008.*
ISBN 978-3-7643-8863-8

F. Lécué and O. Boissier and A. Delteil and A. Léger
Web Service Composition as a Composition of Valid and Robust Semantic Links

F. Lécué and A. Delteil and A. Léger
DL Reasoning and AI Planning for Web Service Composition

F. Lécué and A. Moreau and S. Salibi and P. Bron
Semantic and Syntactic Data Flow in Web Service Composition
In *ICWS*, Beijing, China, September 2008.

F. Lécué and A. Delteil and A. Léger
Optimizing Causal Link based Web Service Composition

M. Shiaa, P. Falcarin, A. Pastor, F. Lécué, E. Silva, L. Ferreira Pires
Automation of Service Composition: Case Study and Implementations
Academic Contributions (2)

F. Lécué and A. Delteil and A. Léger  
Towards the Composition of Stateful and Independent Semantic Web Services  
In *ACM SAC*, pages 2279-2285, Fortaleza, Ceará, Brazil, March 2008.

F. Lécué and A. Delteil  
Making the Difference in Semantic Web Service Composition  

F. Lécué and A. Delteil and A. Léger  
Applying Abduction in Semantic Web Service Composition  

P. Bertoli and J. Hoffmann and F. Lécué and M. Pistore  
Integrating Discovery and Automated Composition: from Semantic Requirements to Executable Code  

F. Lécué and A. Léger  
Semantic Web service composition through a Matchmaking of domain  

F. Lécué and A. Léger  
Semantic Web service composition based on a closed world assumption  
In *ECOWS*, pages 233-242, Zurich, Switzerland, December 2006.
Academic Contributions (3)

F. Lécué and A. Léger
A formal model for semantic Web service composition
In ISWC, pages 385–398, Athens, USA, November 2006.

F. Lécué and A. Léger
A formal model for Web service composition

F. Lécué and A. Léger
Causal link matrix and AI planning: a model for Web service composition
In Workshop "AISC" (ECAI), pages 66–68, Trento, Italy, July 2006.

Additional Reviewer

Program Committee Member
- KES-2008 Invited Session SWEA on Engineered Applications of Semantic Web
- SMR2 (Workshop ISWC 2007, 2008)
- Reviewer of the International Journal of Computers and Applications
Industrial Contributions (1)

- F. Lécué and Samir Salibi
  Spécification de l’intégration du Planificateur avec le générateur sémantique de processus

- F. Lécué and E. Silva and M. Steen
  Automated Composition Framework for Telecom Services
  In *Spice D5.3.3*, May 2008.

- Raúl García-Castro *et al.*
  Architecture of the Semantic Web Framework v2
  In *KnowledgeWeb D1.2.5*, December 2007.

- Raúl García-Castro *et al.*
  Architecture of the Semantic Web Framework
  In *KnowledgeWeb D1.2.4*, January 2007.

- M. Pistore *et al.*
  Prototype for the Integration of Web Service Discovery and Composition
Industrial Contributions (2)

Software

- Composition optimization (February 2008).
- Extended CLM with Non Functional Properties (December 2007).
- Robust Composition of Semantic Web Services (December 2007).
- Functional Level Composition as Causal Link Composition (December 2006).
- Integration/Prototype of service discovery and composition (September 2006).
- Ontology reasoning and WSML based service capability parsing (June 2006).

Patent


Industrial Transfer

- France Telecom AgIS;
- European Project SPICE;
Appendix Outline

7 Main Contributions

8 Appendix
Introduction

As Web services proliferate:
- It becomes possible to compose them at hand;
- ... especially when there is no relevant single service;

Web Service Composition
Selecting and combining existing services, available on the Web, to provide added-value services featuring higher level functionalities.
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**Web Service Composition**

Selecting and combining existing services, available on the Web, to provide added-value services featuring higher level functionalities.
Introduction

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- It becomes possible to compose them at hand;
- ... especially when there is no relevant single service;

Web Service Composition
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Example
Play me all the tracks by singers who are born nearly 100 miles to the living place of the major actor in AI.
Automated, Dynamic and Semantic Web Service Composition

**Driving Idea**

Automated and Dynamic Web service composition in the Semantic Web and in Industrial settings.

**Why Automation?**

The amount of available Web services is huge!

**Why Dynamicity?**

Features of Web services are creation and update on the fly!

**Why Semantics?**

Web services are developed by different organizations that use different conceptual models for presenting services’ features.
## What Kind of Services?

### Semantic Web Services at Functional Level

- **Stateless** Web services; **Behaviour-aware** Web services;
- **Parameters** (i.e., Input and Output) of semantic Web services are **concepts** referred to in an **ontology** $T$:
  - WSDL-S, SA-WSDL (*W3C Proposed Recommendation*);
  - OWL-S profile level;
  - WSMO capability level.

![Ontology T](image-url)