Web Service Composition : Semantic Links based Approach

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Outline

1. Introduction
2. Web Services Composability
3. Automated Web Service Composition Approaches
4. Robust Composition
5. Quality in Web Service Composition
6. Our Approach in a France Telecom Scenario
7. Conclusions and Perspectives
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.
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;

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.
A Web Service is a software application identified by a URI, whose interfaces and binding are capable of being defined, described and discovered by XML artifacts and supports direct interactions with other software applications using XML based messages via Internet-based protocols (W3C definition).

A protocol communication.
Nowadays Web: syntax-based Web.

**Semantic Web** is an extension of current Web in which information is given well-defined meaning.

- **Ontology**: a key enabling technology (RDF, OWL)

**Semantic web principles applied to web services**

- Give a semantics to services description;
- Description languages with a semantics;

![Diagram](image_url)
Web Service Composition

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-Classic
- Contingency
- Conformant

Planning under uncertainty

Classical
- Deterministic
- Complete Initial States

Matthias Klusch
Semantic Web Service Coordination
Book Chapter 2007.
Web Service Composition

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Behavioural Description
- Input/Output Message

Functional Description
- Pre-Conditions
- Post-Conditions
- Name And Description
- Input Parameters
- Output Parameters
Web Service Composition

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Planning under uncertainty

Reactiv vs. Advanced
- Automation
- Expressivity
- Composability
- Optimization
- Applicability

Advanced Semantics
- Pure Planning

Process Level
- OWLS–XPlan2 (Klusch+, 06)
- SHOP2 (Sirin+, 02)
- PLCP (Pistore+, 05)
- Optop (McDermott, 02)
- Mealy Model (Hull+, 03)

Functional Level
- OWLS–XPlan1 (Klusch+, 06)
- WSPLan (Peer, 05)
- MetaComp (Botelho+, 07)
- FFPanner (Hoffmann+, 07)
- GOAL (Pfalzgraf, 06)
- (Lassila, 04)
- Agora–SCP (Rao+, 06)
- Golog-SCP (McIlraith+, 02)
- SAWSDL–SCP (Wu+, 07)
- Optop (McDermott, 02)
- OntoMat–S (Agarwal+, 04)
- Mealy Model (Hull+, 03)
- SemaPlan (Akkiraju+, 06)
- Onto–Comp (Arpinar+, 05)
Web Service Composition

Objective

Context

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

A Proposal

- Semantic links between parameters of services
  → 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**.
Ontology and Description Logics

Elaborate the taxonomy of the TBox:

\[
\begin{align*}
\text{Offer} & \equiv \forall \text{priceOffer}.\text{Price} \land \forall \text{interfacedBy}.\text{Service}, \\
\text{Commercial}_\text{Offer} & \equiv \forall \text{comOffer}.\text{Offer}, \\
\text{NetworkConnection} & \equiv \forall \text{netPro}.\text{Provider} \land \forall \text{netSpeed}.\text{Speed}, \\
\text{SlowNetworkConnection} & \equiv \text{NetworkConnection} \land \forall \text{netSpeed}.\text{Adsl1M}, \\
\text{FastNetworkConnection} & \equiv \text{NetworkConnection} \land \forall \text{netSpeed}.\text{AdslMax}, \\
\text{Speed} & \equiv \forall \text{mBytes}.\text{NoNilSpeed}, \\
\text{Adsl1M} & \equiv \text{Speed} \land \forall \text{mBytes}.\text{1M}; \\
\text{AdslMax} & \equiv \text{Speed} \land \forall \text{mBytes}.\text{Max}, \\
\text{Max} & \subseteq \text{1M} \subseteq \text{NoNilSpeed}, \\
\text{ZipCode} & \subseteq \top, \\
\text{Email} & \subseteq \top, \\
\text{Address} & \subseteq \top, \\
\text{PhoneNum} & \subseteq \top, \\
\text{Invoice} & \subseteq \top, \\
\text{DeliveryID} & \subseteq \top, \\
\text{Service} & \subseteq \top, \\
\text{ZipCode} & \subseteq \neg \text{Email}, \\
\text{Invoice} & \subseteq \neg \text{Service}, \\
\text{IPAddress} & \equiv \text{Address} \land \forall \text{protocol}.\text{IP}, \\
\text{VoIPid} & \equiv \text{Address} \land \forall \text{network}.\text{FTLocal}, \\
\text{VideoDecoder} & \equiv \text{Decoder} \land \forall \text{decrypt}.\text{Video}
\end{align*}
\]
Parameters (i.e., Input and Output) of Web services in semantic Web are concepts referred to in a TBox $\mathcal{T}$ of an ontology $T$:

- WSDL-S, SA-WSDL (*W3C Proposed Recommendation*);
- OWL-S profile level;
- WSMO capability level.
**Semantic Link**: Semantic connection between services;
- ... more particularly between Output and Input parameters;
- ... denoted by $sl_{y,x}$ and valued by $Sim_T(Out_{sy}, In_{sx})$.

### Academic Contributions

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

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... denoted by $sl_{y,x}$ and valued by $Sim_T(Out_{-s_y}, ln_{-s_x})$;

$Sim_T$ is reduced to the five matchmaking functions [M.Paolucci et al. ISWC’02, Li and Horrocks WWW’03]:

- **Exact** i.e., $T \models Out_{-s_y} \equiv ln_{-s_x}$;
- **PlugIn** i.e., $T \models Out_{-s_y} \sqsubseteq ln_{-s_x}$;
- **Subsume** i.e., $T \models ln_{-s_x} \sqsubseteq Out_{-s_y}$;
- **Intersection** i.e., $T \not\models Out_{-s_y} \cap ln_{-s_x} \sqsubseteq \bot$;
- **Disjoint** i.e., $T \models Out_{-s_y} \cap ln_{-s_x} \sqsubseteq \bot$;
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- **Disjoint** i.e., $T \models Out_{sy} \cap In_{sx} \subseteq \bot;$
Computing Semantic links of the set of Services $S_A$, $S_A^-$, $S_A^+$, $S_B$, $S_C$ and $S_D$.

What do you require to do this?
Even if some of the latter match levels are relevant for Web services (i.e., Semantic links) composition e.g.,

- the Exact match ✓ is clearly appropriate;
- the PlugIn match ✓ is also appropriate;
- the Disjoint match ✓ informs about Incompatibility;
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Some match levels are not robust enough for semantic link composition!
- ... indeed the Intersection X and Subsume X match level require some refinements i.e., an Extra Description;

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Some match levels are not robust enough for semantic link composition!

- ... indeed the Intersection ✗ and Subsume ✗ match level require some refinements i.e., an Extra Description;

Robust semantic links in Web service composition are key components to obtain robust composition.
Two Methods to overcome the Robustness problem in Semantic Web Service Composition

Non Robust Semantic Links in Web Service Composition

**The open issue**: How could we transform a non robust semantic link $Sim_T(Out_s_y, In_s_x)$ 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.


Two Methods to overcome the Robustness problem in Semantic Web Service Composition

Non Robust Semantic Links in Web Service Composition

- **The open issue**: How could we transform a non robust semantic link $\text{Sim}_T(Out_{sy}, In_{sx})$ in its robust form?

- **The suggested approach**: by retrieving information contained by $In_{sx}$ and not by $Out_{sy}$ through **Concept Difference** or **Concept Abduction**.

---

S. Brandt, R. Kusters, A. Thurhan.
Approximation and difference in description logics.

T. Di Noia, E. Di Sciascio *et al*.
Abductive matchmaking using description logics.
A Method to overcome the Robustness problem in Semantic Web Service Composition

Concept Difference in Web Service Composition

**Definition (Concept Difference)**

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

$$In_{s_x} \setminus Out_{s_y} := \min \{H | H \sqcap Out_{s_y} \equiv In_{s_x} \sqcap Out_{s_y} \}$$

The *Extra Description* $In_{s_x} \setminus Out_{s_y}$ represents what is underspecified in $Out_{s_y}$ in order to completely satisfy $In_{s_x}$;

$\Rightarrow$ Explain why $Out_{s_y}$ and $In_{s_x}$ can not be chained by a robust semantic link.

The *Common Description* $Out_{s_y} \sqcap In_{s_x}$ refers to information required by $In_{s_x}$ and effectively provided by $Out_{s_y}$.
A Method to overcome the Robustness problem in Semantic Web Service Composition

Concept Difference with an Example (1)

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

$$In_{s_x} \setminus Out_{s_y} := \min \{ H | H \sqsubseteq_d Out_{s_y} \equiv In_{s_x} \sqcap Out_{s_y} \}$$

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

Web service: $s_y$

- $s_y$ Input Parameters
- $s_y$ Output Parameters

Web service: $s_x$

- $s_x$ Input Parameters
- $s_x$ Output Parameters

$NetworkConnection \equiv \forall netSpeed.Speed$
$SlowNetworkConnection \equiv NetworkConnection \sqcap \forall netSpeed.Ads1M$
A Method to overcome the Robustness problem in Semantic Web Service Composition

Concept Difference with an Example (1)

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The difference between two concept descriptions $In_s_x$ and $Out_s_y$ is given by

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Web service: $s_y$

$H \equiv \forall \text{netSpeed}.\text{Adsl1M}$

Web service: $s_x$

$H \equiv \forall \text{netSpeed}.\text{Speed}$

$\equiv \forall \text{netSpeed}.\text{Adsl1M}$
A Method to overcome the Robustness problem in Semantic Web Service Composition

Concept Difference with an Example (2)

Definition (Concept Difference)

The difference between two concept descriptions $In_s_x$ and $Out_s_y$ is given by

$$In_s_x \setminus Out_s_y := \min \{H | H \sqcap Out_s_y \equiv In_s_x \sqcap Out_s_y \}$$

- e.g., in case of non robust semantic link valued by the Intersection match level.
**Definition (Concept Difference)**

The difference between two concept descriptions $\text{In}_s x$ and $\text{Out}_s y$ is given by

$$\text{In}_s x \setminus \text{Out}_s y := \min\{ H \mid H \cap \text{Out}_s y \equiv \text{In}_s x \cap \text{Out}_s y \}$$

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A Method to overcome the Robustness problem in Semantic Web Service Composition

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Definition (Concept Difference)

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\[
\text{In}_s x \setminus \text{Out}_s y := \min \left\{ H \mid H \sqsupseteq \text{Out}_s y \equiv \text{In}_s x \sqcap \text{Out}_s y \right\}
\]

- 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.
A Method to overcome the Robustness problem in Semantic Web Service Composition

Your Turn!!!!

Robustness

- Computing the Difference of semantic links $sl_1, sl_2, sl_3, sl_4$.
- What do you require to do this?
### 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
Semantic Link based Composition

Semantic link matrix: A formal model for Web service composition (2)

**SLM Definition**

- A **SLM** is defined as $M_{p,q}(P(S_{WS} \times (0, 1]))$.
- Rows $r_i, i \in \{1, \ldots, p\}$ are labelled by $\text{Input}(S_{WS}) \subseteq T$;
- Columns $c_j, j \in \{1, \ldots, q\}$ are labelled by $(\text{Input}(S_{WS}) \cup \beta) \subseteq T$;
- Each entry $m_{i,j}$ of a SLM is defined as a set of $(s_y, \text{score}) \in S_{WS} \times (0, 1]$ with $(s_y, \text{score}) := (s_y, \text{Sim}_T(\text{Out}_s, c_j))$.
Semantic Link based Composition

Your Turn!!!!

SLM Construction

- Computing the SLM of $S_A$, $S_A^-$, $S_A^+$, $S_B$, $S_C$ and $S_D$ with goal $\beta := Invoice$.
- What do you require to do this?
AI planning and *SLMs*: A regression-based approach (1)

**Requirements:**
- A TBox $\mathcal{T}$ to infer concepts Matching;

<table>
<thead>
<tr>
<th>Output/Input Parameters</th>
<th>Input Parameters</th>
<th>$I_1$</th>
<th>$I_2$</th>
<th>Decoder</th>
<th>$I \neq {Input{S_{w,*}}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$O_1$</td>
<td>$v_{1,1}$</td>
<td>$v_{1,2}$</td>
<td>$v_{1,i}$</td>
<td>$v_{1,n}$</td>
<td></td>
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<tr>
<td>$O_2$</td>
<td>$v_{2,1}$</td>
<td>$v_{2,2}$</td>
<td>$v_{2,i}$</td>
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</tr>
<tr>
<td>VideoDecoder</td>
<td>fail</td>
<td>fail</td>
<td>plug-in</td>
<td>fail</td>
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<tr>
<td>$O \neq {Output{S_{w,*}}}$</td>
<td>$v_{m,1}$</td>
<td>$v_{m,2}$</td>
<td>$v_{m,i}$</td>
<td>$v_{m,n}$</td>
<td></td>
</tr>
</tbody>
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AI planning and *SLMs*: A regression-based approach (1)

**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;
AI planning and SLMs: A regression-based approach (1)

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- A TBox \( \mathcal{T} \) to infer concepts Matching;
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  - \( S_{Ws} \) i.e., a set of possible state transitions;
  - \( A \) is the Initial state as an ABox. 
    *Individuals* e.g., instances of concepts Email, PhoneNum and ZipCode.
AI planning and *SLMs*: A regression-based approach (1)

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  - $S_{Ws}$ 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 *TBox element* e.g., the concept *Invoice*.
Web Service Composition as an AI Planning Problem

AI planning and SLMs: A regression-based approach (1)

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

<table>
<thead>
<tr>
<th></th>
<th>Email</th>
<th>Decoder</th>
<th>FastNC</th>
<th>IPAddress</th>
<th>PhoneNumber</th>
<th>SlowNC</th>
<th>ZipCode</th>
<th>Invoice</th>
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<td>{(S^a_-, \frac{1}{2}), (S^a_+, 1)}</td>
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<td>0</td>
<td>{(S^-_a, \frac{1}{2}), (S^+_a, 1)}</td>
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<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Z</td>
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AI planning and SLMs: A regression-based approach (1)

- **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 semantic link matrix $\mathcal{M}$ and its semantic links;

- **Methodology:**
  - A Regression-based approach to compute consistent, correct and complete compositions of Web services.
AI planning and SLMs: A regression-based approach (1)

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

Methodology:
- A Regression-based approach to compute consistent, correct and complete compositions of Web services.

Assumptions
- The set of Web services $S_{Ws}$ is closed.
- Implicit goal, Fuzzy Web service together with behaviour description are out of scope.
Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{W_S}, A, \beta \rangle$;

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</table>
Suppose a SLM $\mathcal{M}$ and $\Pi = (\mathcal{S}_{ws}, A, \beta)$;
By the SLM definition, $\mathcal{S}_{ws}$ is referred by $\mathcal{M}$.
Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{Ws}, A, \beta \rangle$;

- By the SLM definition, $A$ is referred by $\mathcal{M}$.

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- in case Email and PhoneNum and ZipCode are in $A$. 

**AI planning and SLMs: A regression-based approach (2)**
Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{Ws}, A, \beta \rangle$;

By the SLM definition, $\beta$ is referred by $\mathcal{M}$.

in case Invoice is in $\beta$. 
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 $\mathcal{M}$.

$$
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0 & 0 & \{(S_c^{3/4})\}} & 0 & 0 & 0 & 0 & \{(S_d^{1})\}} \\
0 & 0 & \{(S_c^{3/4})\}} & \{(S_a^{-\frac{1}{2}),(S_a^{\frac{1}{2}}),(S_a^{+1})\}} & \{(S_b^{1})\}} & \{(S_a^{-1),(S_a^{\frac{1}{2}}),(S_a^{+\frac{3}{4}})\}} & 0 & \{(S_d^{1})\}} \\
0 & 0 & \{(S_a^{-\frac{1}{2}),(S_a^{\frac{1}{2}}),(S_a^{+1})\}} & \{(S_b^{1})\}} & 0 & 0 & 0 & 0 \\
0 & 0 & \{(S_a^{-\frac{1}{2}),(S_a^{\frac{1}{2}}),(S_a^{+1})\}} & 0 & 0 & \{(S_a^{-1),(S_a^{\frac{1}{2}}),(S_a^{+\frac{3}{4}})\}} & 0 & 0
\end{pmatrix}
$$
Web Service Composition as an AI Planning Problem

### AI planning and SLMs: A regression-based approach (2)

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

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

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```
Web Service Composition as an AI Planning Problem

**AI planning and SLMs: A regression-based approach (2)**

- 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 $In$. 

\[
\begin{bmatrix}
\text{Email} & \text{Decoder} & \text{FastNC} & \text{IP Address} & \text{Phone Num} & \text{SlowNC} & \text{Zip Code} & \text{Invoice} \\
0 & 0 & \{(S_a^-, 1/2), (S_a, 1/2), (S_a^+, 1)\} & 0 & 0 & \{(S_a^-, 1), (S_a, 1/2), (S_a^+, 3/4)\} & 0 & 0 \\
0 & 0 & \{(S_c, 3/4)\} & 0 & 0 & 0 & 0 & 0 \\
0 & \{(S_c, 3/4)\} & \{(S_a^-, 1/2), (S_a, 1/2), (S_a^+, 1)\} & \{(S_b, 1/4)\} & 0 & \{(S_a^-, 1), (S_a, 1/2), (S_a^+, 3/4)\} & 0 & \{(S_d, 1)\} \\
0 & \{(S_b, 1/4)\} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \{(S_a^-, 1/2), (S_a, 1/2), (S_a^+, 1)\} & 0 & 0 & \{(S_a^-, 1), (S_a, 1/2), (S_a^+, 3/4)\} & 0 & 0 \\
\end{bmatrix}
\]
AI planning and SLMs: A regression-based approach (2)

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The composition process: a recursive and regression-based approach;
- From the goal $\text{In}$.

$\begin{array}{cccccc}
\text{Email} & \text{Decoder} & \text{FastNC} & \text{IP Address} & \text{Phone Num} & \text{SlowNC} \\
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0 & 0 & 0 & 0 & 0 & 0 \\
0 & \{(S_c, \frac{3}{4})\} & 0 & 0 & 0 & 0 \\
0 & \{(S_c, \frac{3}{4})\} & \{(S_a^-, \frac{1}{2}), (S_a, \frac{1}{2}), (S_a^+, 1)\} & \{(S_b, \frac{1}{4})\} & 0 & \{(S_a^-, 1), (S_a, \frac{1}{2}), (S_a^+, \frac{3}{4})\} \\
0 & 0 & 0 & \{(S_a^-, \frac{1}{2}), (S_a, \frac{1}{2}), (S_a^+, 1)\} & 0 & \{(S_d, 1)\} \\
0 & 0 & \{(S_a^-, \frac{1}{2}), (S_a, \frac{1}{2}), (S_a^+, 1)\} & 0 & 0 & \{(S_d, 1)\} \\
\end{array}$
AI planning and SLMs: A regression-based approach (2)

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

```plaintext
Email  Decoder  FastNC  IP Address  Phone Num  SlowNC  Zip Code
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0      0        \{(S\_c, \frac{3}{4})\} 0        0        0        0        0        \{(S\_d, 1)\}
0      0        \{(S\_c, \frac{3}{4})\} 0        0        \{(S\_b, \frac{1}{4})\} 0        \{(S\_a, 1), (S\_a, \frac{1}{2}), (S\_a, 3/4)\} 0        \{(S\_d, 1)\}
0      0        \{(S\_c, \frac{3}{4})\} 0        \{(S\_b, \frac{1}{4})\} 0        \{(S\_a, 1), (S\_a, \frac{1}{2}), (S\_a, 3/4)\} 0        \{(S\_d, 1)\}
0      0        \{(S\_d, 1), (S\_a, 1)\} 0        \{(S\_a, 1), (S\_a, \frac{1}{2}), (S\_a, 3/4)\} 0        0        \{(S\_d, 1)\}
```

In.

IP.  (S\_d, 1)  (S\_d, 1)

Ph.

De.  (S\_d, 1)
AI planning and SLMs: A regression-based approach (2)

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

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

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

\[ \begin{pmatrix}
\text{Email} & \text{Decoder} & \text{FastNC} & \text{IP Address} & \text{Phone Num} & \text{SlowNC} & \text{Zip Code} & \text{Invoice} \\
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0 & 0 & \{ (S_c, 3/4) \} & 0 & 0 & 0 & 0 & 0 \\
0 & \{ (S_c, 3/4) \} & \{ (S_a^{-}, 1/2), (S_a, 1/2), (S_a^+, 1) \} & \{ (S_b, 1/4) \} & 0 & \{ (S_a^{-}, 1), (S_a^{-}, 1/2), (S_a^+, 3/4) \} & 0 & 0 \\
0 & 0 & \{ (S_a^{-}, 1/2), (S_a, 1/2), (S_a^+, 1) \} & \{ (S_b, 1/4) \} & 0 & 0 & 0 & 0 \\
0 & 0 & \{ (S_a^{-}, 1/2), (S_a, 1/2), (S_a^+, 1) \} & 0 & 0 & \{ (S_a^{-}, 1), (S_a^{-}, 1/2), (S_a^+, 3/4) \} & 0 & 0 \\
\end{pmatrix} \]
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 $In.$, $De.$, the new goal $Fa.$
Suppose a SLM $M$ and $\Pi = \langle S_{WS}, A, \beta \rangle$;

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

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

From the goal $In., De.,$ the new goal $Fa.$
Web Service Composition as an AI Planning Problem

AI planning and SLMs: A regression-based approach (2)

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

The composition process is illustrated using a recursive and regression-based approach. The table below represents the composition process:

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

The composition process is illustrated using a recursive and regression-based approach. The table below represents the composition process:

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

The composition process is illustrated using a recursive and regression-based approach. The table below represents the composition process:

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<th>Email</th>
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The composition process: a recursive and regression-based approach; From the goal $In.$, $De.$, $Fa.$, the new goal $IP$. 

The composition process is illustrated using a recursive and regression-based approach. The table below represents the composition process:

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

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Web Service Composition as an AI Planning Problem

AI planning and SLMs: A regression-based approach (2)

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

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

The composition process:

$$
\begin{bmatrix}
\text{Email} & \text{Decoder} & \text{FastNC} & \text{IP Address} & \text{Phone Num} & \text{SlowNC} & \text{Zip Code} & \text{Invoice} \\
0 & 0 & \{(S_a^{-}, \frac{1}{2}), (S_a^{+}, 1)\} & 0 & 0 & \{(S_a^{-}, 1), (S_a^{+}, \frac{3}{4})\} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \{(S_c, \frac{3}{4})\} & \{(S_a^{-}, \frac{1}{2}), (S_a^{+}, 1)\} & \{(S_b, \frac{1}{4})\} & \{(S_a^{-}, 1), (S_a^{+}, \frac{3}{4})\} & 0 & \{(S_d, 1)\} & 0 \\
0 & \{(S_c, \frac{3}{4})\} & \{(S_a^{-}, \frac{1}{2}), (S_a^{+}, 1)\} & \{(S_b, \frac{1}{4})\} & \{(S_a^{-}, 1), (S_a^{+}, \frac{3}{4})\} & 0 & \{(S_d, 1)\} & 0 \\
0 & 0 & \{(S_a^{-}, \frac{1}{2}), (S_a^{+}, 1)\} & 0 & 0 & \{(S_a^{-}, 1), (S_a^{+}, \frac{3}{4})\} & 0 & 0 \\
0 & \{(S_c, \frac{3}{4})\} & \{(S_a^{-}, \frac{1}{2}), (S_a^{+}, 1)\} & \{(S_b, \frac{1}{4})\} & \{(S_a^{-}, 1), (S_a^{+}, \frac{3}{4})\} & 0 & \{(S_d, 1)\} & 0
\end{bmatrix}
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</table>

\[ S_c \circ S_a \]

\[ (S_d, 1) \]

\[ (S_b, \frac{1}{4}) \]

\[ Ph. \]
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 $\text{In.}$, $\text{De.}$, $\text{Fa.}$, the new goal $\text{IP}$.

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

From the goal $\text{In.}$, $\text{De.}$, $\text{Fa.}$, the new goal $\text{IP}$.
AI planning and SLMs: A regression-based approach (2)

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

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

The diagram illustrates the composition process with states and actions, where $\text{In.}$, $\text{De.}$, $\text{Fa.}$, $\text{Sl.}$, $\text{IP}$, $\text{Ph.}$, and $\text{Zip Code}$ are depicted as nodes and transitions as arrows. The SLM is represented by a state transition matrix, showing the possible transitions between states $S_{\text{d}}$, $S_{\text{a}}$, and $S_{\text{b}}$ with probabilities $\frac{1}{2}$, $\frac{3}{4}$, and $\frac{2}{3}$ respectively.
AI planning and SLMs: A regression-based approach (2)

1. Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{WS}, A, \beta \rangle$;
2. 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 $In.$, $De.$, $Fa.$, the new goal $IP$. 

\[
\begin{pmatrix}
0 & 0 & \{(S_a^-, \frac{1}{2}), (S_a, \frac{1}{2}), (S_a^+, 1)\} & 0 & 0 & \{(S_a^-, 1), (S_a, \frac{1}{2}), (S_a^+, \frac{3}{4})\} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \{(S_c^-, \frac{3}{4})\} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \{(S_d^-, \frac{3}{4}), (S_a^+, \frac{1}{2}), (S_a^- 1)\} & \{(S_b^-, \frac{1}{4})\} & 0 & \{(S_a^-, 1), (S_a, \frac{1}{2}), (S_a^+, \frac{3}{4})\} & 0 & \{(S_d^-, 1)\} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \{(S_a^+, \frac{3}{4})\} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\end{pmatrix}
\]
Web Service Composition as an AI Planning Problem

AI planning and SLMs: A regression-based approach (2)

- 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 $\mathcal{M}$.

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- The composition process: a recursive and regression-based approach;
- From the goal $\text{In.}$, $\text{De.}$, $\text{Fa.}$ and $\text{IP.}$, with a potential solution:
AI planning and *SLMs*: A regression-based approach (2)

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.*, *De.*, *Fa.* and *IP.*, with other solutions e.g.,

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

**Computation of Composition**

- Computing the candidate compositions that achieve goal \( \beta := Invoice \) with Initial Situation \( \mathcal{A} := \{Email, PhoneNum, ZipCode\} \).
  - What do you require to do this?
What about Robust Web Service Composition?

Robust Service Composition

A full Automation of Web service composition?

- Still **not a reality**... especially in case the latter composition is consisting of non robust semantic links;
- However **two ways** to obtain the *Extra Description H* required by non robust semantic links:
  - *discovering* new relevant services but time consuming;
  - *relaxing some constraints* 
    \[
    \text{inf}_{\subseteq} \{ \text{ln}_s \_x \ \text{Out}_s \_y | \langle s_y, \text{Sim}_T(\text{Out}_s \_y, \text{In}_s \_x), s_x \rangle \}.
    \]
What about Robust Web Service Composition?

Robust Service Composition

A full Automation of Web service composition?

- Still **not a reality**... especially in case the latter composition is consisting of **non robust semantic links**;
- However **two ways** to obtain the *Extra Description H* required by non robust semantic links:
  - **discovering** new relevant services but time consuming;
  - **relaxing** some constraints
    \[
    \inf \{ \langle \text{In}_s x, \text{Out}_s y | s_y, \text{Sim}_T (\text{Out}_s y, \text{In}_s x), s_x \rangle \}.
    \]
How to Perform Robust Web Service Composition?

Robust Service Composition... by retrieving new Web services

A full Automation of Web service composition?
- By **discovering** new relevant **Web services**.
- The main constraint is related to the **complexity of composition**.
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- The main constraint is related to the **complexity of composition**.
How to Perform Robust Web Service Composition?

Robust Service Composition... by relaxing some constraints

A full Automation of Web service composition?

- By relaxing some constraints during composition:
  \[ \mathcal{H} := \inf \{ \text{In}_s \text{Out}_y \mid \langle s, \text{Sim}_T(\text{Out}_y, \text{In}_s), s \rangle \} \]
- e.g., by suggesting \( \mathcal{H} \) to the end user as required information the composition process.

For instance

\[ \mathcal{H} := \inf \{ H_1, H_2, H_3, H_4, H_5 \} \]
A full Automation of Web service composition?

- By relaxing some constraints during composition:
  \[ H := \inf \{ \text{ln}_{s_x} \left| \text{out}_{s_y} \right| \langle s_y, \text{Sim}_T(\text{out}_{s_y}, \text{ln}_{s_x}), s_x \rangle \} \]
- e.g., by suggesting \( H \) to the end user as required information the composition process.

For instance

- \( H := \inf \{ H_1, H_2, H_3, H_4, H_5 \} \)
How to Perform Robust Web Service Composition?

Robust Service Composition... by relaxing some constraints

A full Automation of Web service composition?

- By relaxing some constraints during composition:
  \[ \mathcal{H} := \inf \subseteq \{ \text{In}_{s_x} \setminus \text{Out}_{s_y} | \langle s_y, \text{Sim}_T(\text{Out}_{s_y}, \text{In}_{s_x}), s_x \rangle \}. \]
- e.g., by suggesting \( \mathcal{H} \) to the end user as required information the composition process.

For instance

- \( \mathcal{H} := \inf \subseteq \{ H_1, H_2, H_3, H_4, H_5 \} \)

A Concluding Remark

- In both cases the more robust semantic links in a composition the better.
Your Turn!!!!

**Computation of $\mathcal{H}$**

- Computing $\mathcal{H}$ of the following compositions $(S_x, S_y \in \{S_A, S^-_A, S^+_A\})$.
  - What do you require to do this?

```
ABox $\mathcal{A}$

Input Parameters of Web services
- $a : Email$
- $b : PhoneNumber$
- $c : ZipCode$

Goal $\beta$
- Invoice

Output Parameters of Web services
- $\mathcal{X} \in \{Slow, Fast, \emptyset\}$

Semantic Link $sl_1$
- $S_x$ XNetworkConnection FastNC $S_c$
- $S_y$ XNetworkConnection SlowNC $S_d$

Semantic Link $sl_2$
- $S_x$ 

Semantic Link $sl_3$
- $S_c$

Semantic Link $sl_4$
- $S_d$

A service such that $S_x, S_y \in \{S^-_A, S_A, S^+_A\}$

Valid Semantic Links
```

30/66
Automated Computation of Robustness in Composition

Approach

A full Automation of Web service composition?

An agent-based negotiation used to solicit the additional semantic descriptions required for robustness.
## Negotiating Robustness of Composition

### Agent-based Negotiation as a Process for Achieving Robustness in Composition
- **Agents** represent service providers;
- Direct negotiation between agents, no need to involve third party or mediator;
- **Agents** may exchange counter proposals and impose conditions over the use of services;
- The negotiation process is supported by a negotiation protocol.

### Why Yet Another Protocol?
- Typical approaches (e.g. Contract-Net, English Auction) give the initiator more control over the negotiation;
- The role of participants is limited to providing information/proposals.

### In the Proposed Approach
- **Agents** have more control over the negotiation - they can exchange counter proposals;
- Agreements may occur at different levels of granularity.
The Initiator agent sends a CFP to other agent(s);

2. Participant agent decodes XML encoding and consults its service providers regarding the Most Specific Description.

3. If the participant is able to contribute, it will respond with Propose otherwise Refuse.

4. In Propose, the message contains XML encoding of the proposed Extra Description, which is subsumed by the Most Specific Description. This may be accompanied e.g., by cost.

5. On receiving a proposal the initiator agent may decide to accept the proposal or to iterate the process by issuing a revised CFP with new required description. The latter is subsumed by the original Most Specific Description and specifies the elements of which are not yet covered by the set of received proposal.

6. The protocol ends when the Initiator agent sends Accept-Proposal to a set of agent, or when it does not issue a new CFP.
Agents require specific reasoning and decision making mechanisms (M) that feed into various communicative actions (S) in the protocol.

- **M1: Need for Most Specific Description**: A mechanism that enable agents to compute and realize the need for Most Specific Description.
- **M2: Proposal Formation**: A mechanism for agents to compute required information and generate a proposal.
- **M3: Proposal Evaluation and Ranking**: Uses the well known set-partitioning problem for proposal evaluation.
- **M4: Notification of Decision**: A mechanism to notify participating agents about the outcome of their proposals.
- **M5: Acknowledgment**: A mechanism that allow participating agents to acknowledge the use of its information.
Composition Model

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 sl*
  - → Input Parameter
  - ← Output Parameter
- T: Task
- s: Service
Quality Criteria for Semantic Links & Services

$q(sl_{i,j})$ for Elementary Semantic Links $sl_{i,j}$

- **Common Description rate** $q_{cd} \in (0, 1]$:
  \[
  q_{cd}(sl_{i,j}) = \frac{|lcs(Out_{s_i}, In_{s_j})|}{|H_{\in \langle \mathcal{L}, Out_{s_i}, In_{s_j}, T \rangle}| + |lcs(Out_{s_i}, In_{s_j})|}
  \]

- **Matching Quality** $q_m \in (0, 1]$, valued by $\text{Sim}_T(Out_{s_i}, In_{s_j})$:
  (Exact: 1, PlugIn: $\frac{3}{4}$, Subsume: $\frac{1}{2}$, Intersection: $\frac{1}{4}$).

|.| refers to the size of $\mathcal{ALE}$ concept descriptions:

- $|T|$, $|\bot|$, $|A|$, $|\neg A|$ and $|\exists r|$ is 1;
- $|C \sqcap D| = |C| + |D|$;
- $|\forall r.C|$ and $|\exists r.C|$ is $1 + |C|$;

for instance $|\text{Speed} \sqcap \forall mBytes.1M| = 3$. 

Matching Quality $q_m \in (0, 1]$, valued by $\text{Sim}_T(Out_{s_i}, In_{s_j})$:

(Exact: 1, PlugIn: $\frac{3}{4}$, Subsume: $\frac{1}{2}$, Intersection: $\frac{1}{4}$).
Quality Model

Quality Criteria for Semantic Links & Services

$q(sl_{i,j})$ for Elementary Semantic Links $sl_{i,j}$

- **Common Description rate** $q_{cd} \in (0, 1]$: 
  
  $$q_{cd}(sl_{i,j}) = \frac{|lcs(Out_{s_i}, In_{s_j})|}{|H \in \langle L, Out_{s_i}, In_{s_j}, T \rangle| + |lcs(Out_{s_i}, In_{s_j})|}$$

- **Matching Quality** $q_m \in (0, 1]$, valued by $Sim_T(Out_{s_i}, In_{s_j})$ 
  (Exact: 1, PlugIn: $\frac{3}{4}$, Subsume: $\frac{1}{2}$, Intersection: $\frac{1}{4}$).
Quality Model

Quality Criteria for Semantic Links & Services

\( q(sl_{i,j}) \) for Elementary Semantic Links \( sl_{i,j} \)

- **Common Description rate** \( q_{cd} \in (0, 1] \):

\[
q_{cd}(sl_{i,j}) = \frac{|lcs(Out_{s_i}, In_{s_j})|}{|H_{\in \langle \mathcal{L}, Out_{s_i}, In_{s_j}, \mathcal{T} \rangle}| + |lcs(Out_{s_i}, In_{s_j})|}
\]

- **Matching Quality** \( q_m \in (0, 1] \), valued by \( Sim_\mathcal{T}(Out_{s_i}, In_{s_j}) \)
  (Exact: 1, PlugIn: \( \frac{3}{4} \), Subsume: \( \frac{1}{2} \), Intersection: \( \frac{1}{4} \)).

\( q(s_i) \) for Elementary Services \( s_i \)

- **Execution Price** \( q_{pr} \in \mathbb{R}^+ \);
- **Response Time** \( q_t \in \mathbb{R}^+ \).
Quality Model

Quality Criteria for Semantic Links & Services

$q(sl_{i,j})$ for Elementary Semantic Links $sl_{i,j}$

- **Common Description rate** $q_{cd} \in (0, 1]$
  
  \[
  q_{cd}(sl_{i,j}) = \frac{|lcs(Out_{s_i}, In_{s_j})|}{|H_{\in \langle \mathcal{L}, Out_{s_i}, In_{s_j}, \mathcal{T} \rangle}| + |lcs(Out_{s_i}, In_{s_j})|}
  \]

- **Matching Quality** $q_m \in (0, 1]$, valued by $Sim_{\mathcal{T}}(Out_{s_i}, In_{s_j})$
  
  (Exact: 1, PlugIn: $\frac{3}{4}$, Subsume: $\frac{1}{2}$, Intersection: $\frac{1}{4}$).

$q(s_i)$ for Elementary Services $s_i$

- **Execution Price** $q_{pr} \in \mathbb{R}^+$
- **Response Time** $q_t \in \mathbb{R}^+$

QoS-extended quality vector of a semantic link $sl_{i,j}$

\[
q^*(sl_{i,j}) = (q(s_i), q(sl_{i,j}), q(s_j))
\]
Quality Model

Your Turn!!!!

Computation of quality

- Computing the semantic quality $q_{l \in \{cd, m\}}$ of each semantic link $(S_x, S_y \in \{S_A, S_{A^-}, S_{A^+}\})$.
- What do you require to do this?

### ABox $\mathcal{A}$

- $a : $ Email
- $b : $ PhoneNum
- $c : $ ZipCode

### Semantic Links

- $sl_1$: $S_x \xrightarrow{XNetworkConnection} XNetworkConnection \xrightarrow{FastNC} XNetworkConnection \xrightarrow{S_y}$
- $sl_2$: $S_x \xrightarrow{XNetworkConnection} XNetworkConnection \xrightarrow{SlowNC} XNetworkConnection \xrightarrow{S_y}$
- $sl_3$: $S_c \xrightarrow{VideoDecoder} VideoDecoder \xrightarrow{Decoder} S_d$
- $sl_4$: $S_b \xrightarrow{VolPId} VolPId \xrightarrow{IPAddress} S_d$

### Output Parameters of Web services

- $X \in \{Slow, Fast, \emptyset\}$

### Input Parameters of Web services

- $S_x, S_y$ A service such that $S_x, S_y \in \{S_{a^-}, S_a, S_{a^+}\}$

### Valid Semantic Links

- $\Rightarrow$ Goal $\beta$
- $\Rightarrow$ ABox $\mathcal{A}$
Quality Model

Quality Criteria for Composition

Quality Aggregation Rules for Compositions

<table>
<thead>
<tr>
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<tr>
<td></td>
<td>$Q_t$</td>
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Sequential/
AND- Branching

\[
\frac{1}{|sl|} \sum_{sl} q_{cd}(sl) \quad \prod_{sl} q_m(sl) \quad \frac{\sum_s q_t(s)}{\max_s q_t(s)} \quad \sum_s q_{pr}(s)
\]

OR-Branching

\[
\sum_{sl} q_{cd}(sl) \cdot p_{sl} \quad \sum_{sl} q_m(sl) \cdot p_{sl} \quad \sum_s q_t(s) \cdot p_s \quad \sum_s q_{pr}(s) \cdot p_s
\]

Legend

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

**Quality Criteria for Composition**

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**Legend**
- **Semantic Link sl**
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Quality Criteria for Composition

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Legend
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## Quality Criteria for Composition

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Legend:
- Semantic Link $sl$
- $\rightarrow$ Input Parameter
- $\leftarrow$ Output Parameter
- T: Task
- s: Service
# Quality Criteria for Composition

## Quality Aggregation Rules for Compositions

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### A Quality Vector for Web Service Composition

“A” way to differentiate compositions:

$$Q(c) \doteq (Q_{cd}(c), Q_{m}(c), Q_{t}(c), Q_{pr}(c))$$
Computing the semantic quality $Q_{l \in \{cd, m\}}$ of each composition ($S_x, S_y \in \{S_A, S_{A-}, S_{A+}\}$).

- What do you require to do this?
Web Service Composition Driven CSP

CSP Formalization

Formalization as a triple \((T, D, C)\):

- \(T\) is the set of tasks (variables) \(\{T_1, T_2, \ldots, T_n\}\);
- \(D\) is the set of domains \(\{D_1, D_2, \ldots, D_n\}\) i.e., services;
- \(C\) is the set of constraints i.e., local \(C_L\) and global \(C_G\).

\[
e.g., \quad \frac{1}{|s_i^A|} \sum_{s_{i,j}^A} q_{ca}(s_{i,j}^A) \geq \nu, \quad \nu \in [0, 1] \quad \sum_{T_i} q_{pr}(T_i) \leq \nu, \quad \nu \in \mathbb{R}^+
\]

Main Goal to Achieve

- An assignment \((s_i, T_i)_{1 \leq i \leq n}\) i.e., (service, task)
  - with \(s_{i,1 \leq i \leq n} \in D_{i,1 \leq i \leq n}\);
  - which satisfies all the constraints \(C\).
What is the number of potential compositions of $n$ tasks with $m$ potential services per task?
Your Turn!!!!

Computation of quality

- Modelling the CSP problem using \((S_x, S_y \in \{S_A, S^-_A, S^+_A\})\)?

- What do you require to do this?

\[
\begin{align*}
\text{Email} & \quad \text{PhoneNum} \quad \text{ZipCode} \\
S_x & \quad X_{\text{NetworkConnection}} \quad \text{FastNC} \\
\text{Semantic Link } sl_1 & \\
S_y & \quad X_{\text{NetworkConnection}} \quad \text{SlowNC} \\
\text{Semantic Link } sl_2 & \\
S_c & \quad \text{VideoDecoder} \quad \text{Decoder} \\
\text{Semantic Link } sl_3 & \\
S_b & \quad \text{VoIPId} \quad \text{IPAddress} \\
\text{Semantic Link } sl_4 & \\
S_d & \quad \text{Invoice} \\
\end{align*}
\]

\(X \in \{\text{Slow, Fast, } \emptyset\}\)

\(S_x, S_y\) A service such that \(S_x, S_y \in \{S^-, S, S^+\}\)  
\(\Rightarrow\) Valid Semantic Links

\(\Rightarrow\) Output Parameters of Web services
\(\Rightarrow\) Input Parameters of Web services

\(\text{Goal } \beta\)

\(\text{ABox } A\)
A Scalable Approach

A Stochastic Search Method (1)

Principles

- Sacrificing completeness (i.e., all solutions) for speed;
- Based on a simple idea: computing “a single” solution.

Our Approach

- Adaptation of the Hill Climbing algorithm.
  - Appropriate for a large number of services.

S. Russell and P. Norvig.

Computational Complexity

- CSP based search methods: Exponential!
- Stochastic search methods (e.g., Hill Climbing) scale better!
A Scalable Approach

A Stochastic Search Method (2)

Requirements

- An *evaluation function* $f$ for each composition $c$:
  \[
  f(c) = \frac{\omega_{cd}\hat{Q}_{cd}(c) + \omega_{m}\hat{Q}_{m}(c)}{\omega_{pr}\hat{Q}_{pr}(c) + \omega_{t}\hat{Q}_{t}(c)}
  \]

- An *adjacency function*: $c_1$ and $c_2$ are adjacent to each other if they differ in exactly one assignment $(s, T)$.

Algorithm in Details

1) Let’s start with a random composition $c_{\text{final}}$.
2) *Evaluation* of all $c_i, 1 \leq i \leq n$ adjacent to $c_{\text{final}}$.
   - If $\exists i$ such that $f(c_{\text{final}}) \leq f(c_i)$ then $f(c_{\text{final}}) \leftarrow f(c_i)$.
3) Iteration until all constraints are satisfied by $c_{\text{final}}$.
4) If no solution, constraints relaxing.
Stochastic Search Method

- Let’s elaborate the adjacency function?
  - What do you require to do this?
- Compute the *best* composition regarding the value of their evaluation function?
  - What do you require to do this?

Legend

- Semantic Link $sl$
- Input Parameter
- Output Parameter
- T: Task
- s: Service
A Scalable Approach

Experimentation

Evolution of Constraints Satisfaction
- The more tasks, services the more time consuming!

Evolution of Composition Quality
- Optimal composition: High Time consuming!
- Compositions that satisfy constraints: More scalable!

Search Process vs. DL Reasoning ($|T| > 100$, $|s| > 350$)
- DL reasoning is the most time consuming process!
  - Large number of potential semantic links.
  - Critical complexity of DL abduction.

Vs. State-of-the-art Approaches ($T = 300$ $|s| > 280$)
- Adoption of stochastic search method for large domains!
  - No exponential search required.
## Composition Optimization Driven CSOP

### CSOP Formalization \((T, D, C, f)\)

- **\(T\)** is the set of tasks (variables) \(\{T_1, T_2, \ldots, T_n\}\);
- **\(D\)** is the set of domains \(\{D_1, D_2, \ldots, D_n\}\) i.e., services;
- **\(C\)** is the set of constraints i.e., local \(C_L\) and global \(C_G\);

\[
\frac{1}{|s_{i,j}^A|} \sum_{s_{i,j}^A} q_{ca}(s_{i,j}^A) \geq \nu, \quad \nu \in [0, 1]
\]

\[
\sum_{T_i} q_{pr}(T_i) \leq \nu, \quad \nu \in \mathbb{R}^+
\]

- **\(f\)** is an evaluation function.

### Main Goal to Achieve

- An **assignment** \((s_i, T_i)_{1 \leq i \leq n}\) i.e., (service, task) Problem
  - with \(s_{i,1 \leq i \leq n} \in D_{i,1 \leq i \leq n}\);
  - which satisfies all the **constraints** \(C\);
  - which is optimal in terms of **QoS** or **functional** quality.
Local and Naive Global Selection

Local Selection on $s_{i,j}^A$

- Enforcing specific services for both tasks $T_i$ and $T_j$;
- Quality constraints may be not satisfied, leading to a suboptimal composition.

Naive Global Selection

- Exhaustive search of the optimal composition;
  ⇒ Exponential in the number of abstract semantic links.

Our Approach

An integer linear programming IP based global selection, which
- further constrains semantic links;
- meets a given objective.
Optimal Composition and IP Problem

The problem of computing an optimal composition is mapped into an IP problem.

Inputs of the IP Problem

- An *objective function*;
- A set of *integer variables* (restricted to values 0 or 1);
- A set of *constraints* (equalities or inequalities)

where both the *objective function* and the *constraints* are linear.

Outputs of the IP Problem

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

Step 1: Compositions Computation

Computation of $Q_{l,I}^{\lambda, 1 \leq \lambda \leq p}$, i.e., quality values of the $p$ potential compositions.

Step 2: Scaling

Quality values $Q_r^\lambda$, $Q_{cd}^\lambda$, $Q_m^\lambda$ are then scaled according to:

$$Q_I^\lambda = \begin{cases} \frac{Q_I^\lambda - Q_I^{\min}}{Q_I^{\max} - Q_I^{\min}} & \text{if } Q_I^{\max} - Q_I^{\min} \neq 0 \\ 1 & \text{if } Q_I^{\max} - Q_I^{\min} = 0 \end{cases}$$

for $l \in \{r, cd, m\}$.

Step 3: Objective Function

$$\max_{1 \leq \lambda \leq p} \left( \sum_{l \in \{r, cd, m\}} \left( \tilde{Q}_l^\lambda \times \omega_l \right) \right)$$
Scaling candidate compositions

- Computing the scale based compositions $Q_{l \in \{r, cd, m\}} \sim \lambda$.
- What do you require to do this?

$X \in \{\text{Slow, Fast, } \emptyset\}$

Output Parameters of Web services

Input Parameters of Web services

$S_x, S_y$ A service such that $S_x, S_y \in \{S^-_a, S_a, S^+_a\}$

Goal $\beta$

ABox $\mathcal{A}$

Valid Semantic Links
An integer variable $y_{i,j}^k \in \{0, 1\}$ for every candidate link $s_{i,j}^k$ of an abstract link $s_{i,j}^A$ indicates the selection or exclusion of link $s_{i,j}^k$ in the IP problem.
Constraints of IP Problem

**Allocation Constraint**

Only one candidate link is selected for each abstract link $sl_{i,j}^A$.

$$\sum_{k=1}^{n} y_{i,j}^k = 1, \ \forall sl_{i,j}^A$$

Legend

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

T: Task
s: Candidate Service
Constraints of IP Problem

Incompatibility Constraint

Some semantic links $s_{i,j}^k$ and $s_{j,\beta}^l$ are incompatible in a composition.

$y_{i,j}^k + y_{j,\beta}^l \leq 1, \forall s_{i,j}^A \forall s_{j,\beta}^A$
### Constraints of IP Problem

#### Constraints on Quality values of Compositions

- **Robustness** Constraint for capturing and constraining the robustness quality of a semantic link composition;
- **Common Description Rate** Constraint;
- **Matching Quality** Constraint.

#### Local Constraints

Such constraints can predicate on properties of a single link (e.g., *local robustness*).
### IP Based Approach

**Flexibility (and Extension) of Constraints**

#### Suggested Constraints (*Reminder*)

- Allocation Constraint;
- Incompatibility Constraint;
- Constraints on **Quality values** of Compositions:
  - Robustness Constraint;
  - Common Description Rate Constraint;
  - Matching Quality Constraint.
- Local Constraints.

⇒ The method for **translating** the problem of selecting an **optimal composition** into an **IP problem** is **generic**.

⇒ **Other semantic criteria** to value semantic links can be **accommodated**.
Your Turn!!!!

Modeling IP based Optimal Web Service Composition

- Modeling the Composition optimization problem in an IP Problem.
- What do you require to do this?

```
Modeling the Composition optimization problem in an IP Problem.

Goal
Composition

Semantic Link \( sl_1 \)
- Output Parameters of Web services
- Input Parameters of Web services

\( X \in \{ \text{Slow, Fast, } \emptyset \} \)

Semantic Link \( sl_2 \)

Semantic Link \( sl_3 \)

Semantic Link \( sl_4 \)

\( S_x, S_y \) A service such that \( S_x, S_y \in \{ S_a^-, S_a, S_a^+ \} \)

\( \frac{55}{66} \)
```
IP Based Approach

Computational Complexity and Experimentation

**Computational Complexity**
- The optimization problem is equivalent to an IP problem.  
  ⇒ NP-hard!

**Experimentation**
- Exhaustive search based: High computation cost.
- IP based: Acceptable computation cost.

![Graphs showing computational complexity and experimentation results](image-url)
A Genetic Algorithm based Method

Principles for computing the optimal solution

- simulating the evolution of an initial population until survival of best fitted compositions satisfying constraints $C$.

GA Parameters

- Genotype.
- Initial Population: compositions randomly selected.
- Fitness Function: $f(c)$

$$f(c) = \frac{\omega_{cd} \hat{Q}_{cd}(c) + \omega_m \hat{Q}_m(c)}{\omega_{pr} \hat{Q}_{pr}(c) + \omega_t \hat{Q}_t(c)} - \omega_{pe} \frac{\text{gen}}{\text{maxgen}} \sum_{l \in \{pr,t,cd,m\}} \left( \frac{\Delta \hat{Q}_l}{\hat{Q}_l^{\text{max}}(c) - \hat{Q}_l^{\text{min}}(c)} \right)^2$$

- Operators on Genotypes: crossover, mutation, selection.
- Stopping Criterion: until the constraints are met!
Modeling GA based Optimal Web Service Composition

- Modeling the Composition optimization problem in an GA Problem.
  - What do you require to do this?
Benefits of Combining QoS and Functional Criteria

- Limiting the costs of data integration.

Evolution of Composition Quality (up to $|T| = 500$, $|s| = 500$)

- Complexity in the number of tasks and services;
- Variables: population size and number of generations;
- ... but could be inappropriate.

GA Process vs. DL Reasoning (up to $|T| = 30$, $|s| > 35$)

- DL reasoning is the most time consuming process!
  - Large number of potential semantic links.
  - Critical complexity of DL Difference.

Vs. State-of-the-art Approaches

- Better fitness values for the optimal composition;
The Reference Architecture

End User’s Request
Service Goal $s_g$

$s_g := \langle A, \beta \rangle$

Repository of Semantic Web Services $S_{WS}$

Impl:jUDDI

Services Parsing

ServiceImpls

Impl:Naive

Relevant Services $S_{WS}$

Not Found

Impl:WSML

Not Found

Candidate Compositions $S_{WSC}$

Impl:WSML

Impl:Java, perl-based

Golog

Details

Domain Ontology

Implementation Details

60/66
Industrial Scenarios in Use

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.
Applications

Industrial Scenarios in Use - An Example

Internet Package

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

Nowdays 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>Parameters</th>
<th>Computation Time in ms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>(0, 1000)</td>
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</tr>
<tr>
<td>Semantic Links oriented</td>
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<td>74</td>
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<td></td>
<td>Nb Inputs, Outputs</td>
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<td>Composition Optimization</td>
<td>Nb Services</td>
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<td>260</td>
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<tr>
<td></td>
<td>Nb Candidate semantic Link</td>
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<td>100</td>
</tr>
</tbody>
</table>
Contributions

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

2. SME³-Comp (SEMantic wEb sERVicE) Software:
   - (Robust) Semantic Link, SLM;
   - 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. Improving **Quality of Composition**:
   - Coupling Quality of **Service** and **Semantic Links**;
   - Coupling **Composition** and **Discovery**.
5. Investigating in further **Scenarios, Benchmarks** *(SWS Challenge)*.
Future Work

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   - Coupling Composition and Discovery.
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Thanks for your attention!

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