Web Service Composition : Semantic Links based Approach

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Ecole des Mines de Saint-Etienne, France

http://tiny.cc/OQWhQ
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
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.
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:**

```
Web Services
  UDDI, WSDL, SOAP

WWW
  URI, HTML, HTTP

Intelligent Web Services
  RDF, RDF(S), OWL
```

*Bringing the web to its full potential*
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

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

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Planning under uncertainty

Behavioural Description

Process Level

Functional Description

Input/Output Message

Functional Level

Pre-Conditions

Name And Description

Post-Conditions

Input Parameters

Output Parameters
Web Service Composition

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Planning under uncertainty

Process Level

Functional Level

• Automation
• Expressivity
• Composability
• Optimization
• Applicability

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)
WSPLan (Peer, 05)
FFPanner (Hoffmann+, 07)
(Goll-SCP (McIlraith+, 02)
Optop (McDermott, 02)
MetaComp (Botelho+, 07)
GOAL (Pfalzgraf, 06)
Agora−SCP (Rao+, 06)
SAWSDL−SCP (Wu+, 07)
OntoMat−S (Agarwal+, 04)
(Medjahed+, 03)
SemaPlan (Akkiraju+, 06)
Onto−Comp (Arpinar+, 05)

Introduction
Composability
Composition
Robustness
Quality
Evaluation
Conclusions
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:

\[\text{Offer} \equiv \forall \text{priceOffer} . \text{Price} \land \forall \text{interfacedBy} . \text{Service}, \text{Commercial\_offer} \equiv \forall \text{comOffer} . \text{Offer},\]

\[\text{NetworkConnection} \equiv \forall \text{netPro} . \text{Provider} \land \forall \text{netSpeed} . \text{Speed},\]

\[\text{SlowNetworkConnection} \equiv \text{NetworkConnection} \land \forall \text{netSpeed} . \text{Adsl1M},\]

\[\text{FastNetworkConnection} \equiv \text{NetworkConnection} \land \forall \text{netSpeed} . \text{AdslMax},\]

\[\text{Speed} \equiv \forall \text{mBytes} . \text{NoNilSpeed},\]

\[\text{Adsl1M} \equiv \text{Speed} \land \forall \text{mBytes} . 1M; \text{AdslMax} \equiv \text{Speed} \land \forall \text{mBytes} . \text{Max},\]

\[\text{Max} \sqsubseteq 1M \sqsubseteq \text{NoNilSpeed}, \text{ZipCode} \sqsubseteq \top, \text{Email} \sqsubseteq \top, \text{Address} \sqsubseteq \top, \text{PhoneNum} \sqsubseteq \top,\]

\[\text{Invoice} \sqsubseteq \top, \text{DeliveryID} \sqsubseteq \top, \text{Service} \sqsubseteq \top,\]

\[\text{ZipCode} \sqsubseteq \neg \text{Email}, \text{Invoice} \sqsubseteq \neg \text{Service},\]

\[\text{IPAddress} \equiv \text{Address} \land \forall \text{protocol}\_\text{IP}, \text{VoIPId} \equiv \text{Address} \land \forall \text{network}\_\text{FTLocal},\]

\[\text{VideoDecoder} \equiv \text{Decoder} \land \forall \text{decrypt}\_\text{Video}\]
Web Service Composition

Web Services at Functional Level

- **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.
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 $Sim_T(Out_{sy}, In_{sx})$;

### Academic Contributions

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

- **F. Lécué and A. Léger**
  Semantic Web service composition based on a closed world assumption
  In *ECOWS*, pages 233-242, Zurich, Switzerland, December 2006.
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$Sim_T$ is reduced to the five matchmaking functions [M. Paolucci et al. ISWC’02, Li and Horrocks WWW’03]:

- **Exact** i.e., $T \models Out_{_s_y} \equiv In_{_s_x}$;
- **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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Semantic Link

Your Turn!!!!

Semantic Links

- 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**;
Limits of Standard Matching functions

- 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;
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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**;

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**e.g.**, 

```
<table>
<thead>
<tr>
<th>S_y Output Parameters</th>
<th>S_x Input Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web service: s_y</td>
<td>SlowNetWork Connection</td>
</tr>
<tr>
<td></td>
<td>S_x Output Parameters</td>
</tr>
</tbody>
</table>
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- the Disjoint match ✓ informs about Incompatibility;

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.
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 $\text{Sim}_T(Out_{s_y}, In_{s_x})$ 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**.

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 $\text{In}_s x$ and $\text{Out}_s y$ 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 $In_s x$;

⇒ 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)

**Definition (Concept Difference)**

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

$$In_{s_x} \setminus Out_{s_y} := \min\{H \mid H \sqsubseteq \text{d} \equiv In_{s_x} \sqcap Out_{s_y} \}$$

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

---

**Diagram**

- **Web service: $s_y$**
  - $S_y$ Input Parameters
  - $S_y$ Output Parameters
  - $\text{Connection} \equiv \forall \text{netSpeed.Speed}

- **Web service: $s_x$**
  - $S_x$ Input Parameters
  - $S_x$ Output Parameters
  - $\text{Connection} \equiv \forall \text{netSpeed.Ads1M}$
A Method to overcome the Robustness problem in Semantic Web Service Composition

Concept Difference with an Example (1)

Definition (Concept Difference)

The difference between two concept descriptions $In_sx$ and $Out_sy$ is given by

$$In_sx \setminus Out_sy := \min\{H|H \cap Out_sy \equiv In_sx \cap Out_sy\}$$

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

**Example:**

- **Sy Output Parameters:** $\exists \text{netSpeed}.Adsl1M$
- **Sy Input Parameters:** $\forall \text{netSpeed}.Speed$
- **Web service:** $s_y \sqcap H$
- **Sx Input Parameters:** $\forall \text{netSpeed}.Adsl1M$
- **Sx Output Parameters:** $\exists \text{netSpeed}.Adsl1M$
- **Web service:** $s_x$
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 $\text{In}_s_x$ and $\text{Out}_s_y$ is given by

$$\text{In}_s_x \setminus \text{Out}_s_y := \min\{H|H \cap \text{Out}_s_y \equiv \text{In}_s_x \cap \text{Out}_s_y\}$$

- e.g., in case of non robust semantic link valued by the Intersection match level.
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 $\text{In}_s^x$ and $\text{Out}_s^y$ is given by

$$\text{In}_s^x \setminus \text{Out}_s^y := \min\{H | H \sqcap \text{Out}_s^y \equiv \text{In}_s^x \sqcap \text{Out}_s^y\}$$

- e.g., in case of non robust semantic link valued by the Intersection match level.
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 \( \text{In}_{s_x} \) and \( \text{Out}_{s_y} \) is given by

\[
\text{In}_{s_x} \setminus \text{Out}_{s_y} := \min \{ H | H \cap \text{Out}_{s_y} \equiv \text{In}_{s_x} \cap \text{Out}_{s_y} \}
\]

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?

VoiceOverIP

<table>
<thead>
<tr>
<th>Service $S_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>VideoDecoder</td>
</tr>
<tr>
<td>Decoder</td>
</tr>
<tr>
<td>PhoneNumber</td>
</tr>
<tr>
<td>IPAddress</td>
</tr>
<tr>
<td>VolPlId</td>
</tr>
<tr>
<td>Invoice</td>
</tr>
</tbody>
</table>

TVOverIP

<table>
<thead>
<tr>
<th>Service $S_b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Connection</td>
</tr>
<tr>
<td>Slow</td>
</tr>
<tr>
<td>PhoneNumber</td>
</tr>
</tbody>
</table>

Adsl

<table>
<thead>
<tr>
<th>Eligibility Service $S_a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhoneNumber</td>
</tr>
<tr>
<td>ZipCode</td>
</tr>
<tr>
<td>EMail</td>
</tr>
</tbody>
</table>

Semantic Link $sl_1$ (Subsume Match ⊒)

Semantic Link $sl_2$ (Subsume Match ⊒)

Semantic Link $sl_3$ (PlugIn Match ⊑)

Semantic Link $sl_4$ (Intersection Match ⊓)
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 $M_{p,q}(\mathcal{P}(S_{Ws} \times (0, 1)))$.
  - 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 $(s_y, \text{score}) := (s_y, \text{Sim}_T(\text{Out}_{s_y}, c_j))$. 

$$
\begin{pmatrix}
    m_{1,1} & m_{1,2} & \ldots & \cdots & m_{1,q} \\
    m_{2,1} & m_{2,2} & \ldots & \cdots & m_{2,q} \\
    \vdots & \vdots & m_{i,j-1} & \cdots & \vdots \\
    m_{p,1} & m_{p,2} & \ldots & \cdots & m_{p,q}
\end{pmatrix}
$$

$\text{Input}(S_{Ws}) \subseteq T$

$\beta \subseteq T$

"Seminar Link" 

"Web service $S_y$" 

"T#$\text{Concept}_i$

"T#$\text{Out}_{s_y}$, $T#$\text{Concept}_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 $T$ to infer concepts Matching;

<table>
<thead>
<tr>
<th>Output/Input Parameters</th>
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</tr>
</thead>
<tbody>
<tr>
<td>$I_1$</td>
<td>$I_2$</td>
</tr>
<tr>
<td>$O_1$</td>
<td>$v_{1,1}$</td>
</tr>
<tr>
<td>$O_2$</td>
<td>$v_{2,1}$</td>
</tr>
<tr>
<td>$VideoDecoder$</td>
<td>fail</td>
</tr>
<tr>
<td>$O # {Output{S_W}}$</td>
<td>$v_{n,1}$</td>
</tr>
</tbody>
</table>

Ontology $T$
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)

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. Individuals e.g., instances of concepts Email, PhoneNum and ZipCode.

PhoneNum
#+33618404915

Email
freddy.lecue@orange-ftgroup.com

ZipCode
#35512
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 TBox element e.g., the concept Invoice.
AI planning and SLMs: A regression-based approach (1)

Requirements:
- A TBox $\mathcal{T}$ to infer concepts Matching;
- An AI planning problem $\Pi = \langle S_{\text{Ws}}, A, \beta \rangle$;
  - $S_{\text{Ws}}$ 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;

```
    Email  Decoder  FastNC  IPAddress  PhoneNum  SlowNC  ZipCode  Invoice
    0      0        (Sa^-, 1/2, Sa, 1/2, Sa^+)  0        (S^-1, Sa, 1/2, Sa^+)  0        0  0
    0      0        0                0      0        0        0  0
    0      (Sc, 3/4) 0                0      0        0        0  0
    0      (Sc, 3/4) (Sa^-, 1/2, Sa, 1/2, Sa^+) 0      (S^-1, Sa, 1/2, Sa^+)  0        0  0
    0      0        0                (Sb, 1/4) 0        0        0  0
    0      0        (Sa^-, 1/2, Sa, 1/2, Sa^+) 0      0        0        0  0
```
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 $\Pi = \langle S_{Ws}, A, \beta \rangle$;
    - $S_{Ws}$ 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.

**Assumptions**

- The set of Web services $S_{Ws}$ is **closed**.
- **Implicit goal, Fuzzy Web service together with behaviour description are out of scope.**
Web Service Composition as an AI Planning Problem

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

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

<table>
<thead>
<tr>
<th></th>
<th>Email</th>
<th>Decoder</th>
<th>FastNC</th>
<th>IP Address</th>
<th>Phone Num</th>
<th>SlowNC</th>
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</tr>
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<td>(S_d^- , 1)</td>
</tr>
</tbody>
</table>
Suppose a $SLM \mathcal{M}$ and $\Pi = (\mathcal{S}, \mathcal{A}, \beta)$;
By the $SLM$ definition, $\mathcal{S}$ is referred by $\mathcal{M}$.
AI planning and \textit{SLMs}: A regression-based approach (2)

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

\begin{equation}
\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\end{pmatrix}
\end{equation}

in case \textit{Email} and \textit{PhoneNum} and \textit{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 $\mathcal{M}$.

```
<table>
<thead>
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</table>
```

- in case Invoice is in $\beta$. 

in case Invoice is in $\beta$. 

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

```
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>
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</table>
**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 $\mathcal{M}$.

<table>
<thead>
<tr>
<th></th>
<th>Email</th>
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</thead>
<tbody>
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<td>${(S_b, 1/4)}$</td>
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</tbody>
</table>

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

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 \( In \).
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 $In$. 

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<th>Zip Code</th>
<th>Invoice</th>
</tr>
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</table>
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 $In.$, the new goal $De$. 

\( \begin{array}{cccccccc}
\text{Email} & \text{Decoder} & \text{FastNC} & \text{IP Address} & \text{Phone Num} & \text{SlowNC} & \text{Zip Code} & \text{Invoice} \\
0 & 0 & \{(S_{a}^{-}, \frac{1}{2}), (S_{a}, \frac{1}{2}), (S_{a}^{+}, 1)\} & 0 & 0 & \{(S_{a}^{-}, 1), (S_{a}, \frac{1}{2}), (S_{a}^{+}, \frac{3}{4})\} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \{(S_{c}, \frac{3}{4})\} & 0 & 0 & 0 & \{(S_{d}, 1)\} & 0 \\
0 & 0 & \{(S_{a}, \frac{3}{4}), (S_{c}, \frac{3}{4}, (S_{a}^{+}, 1)\} & \{(S_{b}, \frac{1}{4})\} & 0 & \{(S_{a}^{-}, 1), (S_{a}, \frac{1}{2}), (S_{a}^{+}, \frac{3}{4})\} & 0 & \{(S_{d}, 1)\} \\
0 & 0 & 0 & \{(S_{b}, \frac{1}{4})\} & 0 & 0 & 0 & 0 \\
0 & 0 & \{(S_{a}^{-}, \frac{1}{2}), (S_{a}, \frac{1}{2}), (S_{a}^{+}, 1)\} & 0 & 0 & \{(S_{a}^{-}, 1), (S_{a}, \frac{1}{2}), (S_{a}^{+}, \frac{3}{4})\} & 0 & 0 \\
\end{array} \)
AI planning and \textit{SLMs}: A regression-based approach (2)

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

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

\begin{table}[h]
\begin{tabular}{|c|c|c|c|c|c|c|}
\hline
Email & Decoder & FastNC & IP Address & Phone Num & SlowNC & Zip Code & Invoice \\
\hline
0 & 0 & $\{(S_a^- , \frac{1}{2}),(S_a^+ , 1)\}$ & 0 & 0 & $\{(S_a^- , 1),(S_a^+ , 3, \frac{3}{4})\}$ & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & $(S_d, 1)$ & 0 \\
0 & $\{(S_c, \frac{3}{4})\}$ & 0 & 0 & 0 & 0 & $(S_d, 1)$ & 0 \\
0 & $\{(S_a^+ , 1, \frac{1}{2})\}$ & 0 & $\{(S_a^- , 1),(S_a^+ , 1, \frac{3}{4})\}$ & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & $(S_d, 1)$ & 0 \\
0 & $\{(S_c, \frac{3}{4})\}$ & 0 & 0 & 0 & 0 & $(S_d, 1)$ & 0 \\
0 & $\{(S_a^+ , 1, \frac{3}{4})\}$ & 0 & 0 & 0 & 0 & 0 & 0 \\
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\hline
\end{tabular}
\end{table}
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 $In.$, $De.$, the new goal $Fa.$
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 $\mathcal{M}$ 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 $Fa.$
Web Service Composition as an AI Planning Problem

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

- Suppose a SLM $\mathcal{M}$ and $\Pi = \langle S_{W_0}, A, \beta \rangle$;
- By the SLM definition, $S_{W_0}$, $A$ and $\beta$ are referred by $\mathcal{M}$.

```
Email  Decoder  FastNC  IP Address  Phone Num  SlowNC  Zip Code  Invoice
0 0 0 \{(S_a^-, 1/2), (S_a^+, 1)\} 0 0 \{(S_a^-, 1), (S_a^+, 3/4)\} 0 0 \{(S_d, 1)\}
0 0 0 \{(S_c, 3/4)\} 0 0 0 0 \{(S_d, 1)\}
0 0 0 \{(S_c, 3/4)\} 0 0 0 0 \{(S_d, 1)\}
0 0 0 \{(S_a^-, 1/2), (S_a^+, 1)\} 0 0 \{(S_a^-, 1), (S_a^+, 3/4)\} 0 0 \{(S_d, 1)\}
```

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

```
? \rightarrow IP. \rightarrow (S_d, 1) \rightarrow (S_d, 1) \rightarrow Ph. 
```

$S_c \circ S_a$
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 $IP.$

$\begin{array}{cccccccc}
\text{Email} & \text{Decoder} & \text{FastNC} & \text{IP Address} & \text{Phone Num} & \text{SlowNC} & \text{Zip Code} & \text{Invoice} \\
\hline
0 & 0 & \{(S_a^- , \frac{1}{2}), (S_a^+ , 1)\} & 0 & 0 & \{(S_a^- , 1), (S_a^+ , \frac{3}{4})\} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \{(S_c, \frac{3}{4})\} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \{(S_a^- , \frac{1}{2}), (S_a^+ , 1)\} & 0 & 0 & \{(S_a^- , 1), (S_a^+ , \frac{3}{4})\} & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \{(S_a^- , \frac{1}{2}), (S_a^+ , 1)\} & 0 & 0 & \{(S_a^- , 1), (S_a^+ , \frac{3}{4})\} & 0 & 0 \\
\end{array}$
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 $IP$.
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 $IP$. 
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 $IP.$
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The composition process: a recursive and regression-based approach;

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

\begin{align*}
\text{Email} &\rightarrow \text{Decoder} \\
\text{FastNC} &\rightarrow \text{IP Address} \\
\text{FastNC} &\rightarrow \text{Phone Num} \\
\text{SlowNC} &\rightarrow \text{Zip Code} \\
\text{Zip Code} &\rightarrow \text{Invoice}
\end{align*}
AI planning and SLMs: A regression-based approach (2)

- 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 $In.$, $De.$, $Fa.$ and $IP.$, with a potential solution:

![Diagram](image-url)

### Table

<table>
<thead>
<tr>
<th>Email</th>
<th>Decoder</th>
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<th>IP Address</th>
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<th>Invoice</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>${(S_a^- , 1/2), (S_a^+ , 1)}$</td>
<td>0</td>
<td>0</td>
<td>${(S_a^- , 1), (S_a^+ , 3/4)}$</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>(S_d, 1)</td>
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<tr>
<td>0</td>
<td>0</td>
<td>${(S_c , 3/4)}$</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
<td>${(S_c , 3/4)}$</td>
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<td>0</td>
<td>(S_d, 1)</td>
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The composition process: a recursive and regression-based approach;

From the goal $In.$, $De.$, $Fa.$ and $IP.$, with other solutions e.g.,
Your Turn!!!!

Computation of Composition

- Computing the candidate compositions that achieve goal
  \[ \beta \coloneqq Invoice \text{ with Initial Situation} \]
  \[ \mathcal{A} \coloneqq \{ Email, PhoneNum, ZipCode \}. \]
- 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

$$\inf \{\text{in}_{s_x} \text{out}_{s_y} \mid s_y, \text{Sim}_T(\text{out}_{s_y}, \text{in}_{s_x}), s_x\}.$$
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    \[
    \inf_{\subseteq} \{ \text{ln}_{s_x} \setminus \text{out}_{s_y} | \langle s_y, \text{Sim}_T(\text{out}_{s_y}, \text{ln}_{s_x}), s_x \rangle \}.
    \]
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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- By **discovering** new relevant **Web services**.
- The main constraint is related to the **complexity of composition**.
Robust Service Composition... by relaxing some constraints

A full Automation of Web service composition?

- By relaxing some constraints during composition:
  \[ \mathcal{H} := \inf \{ In_s \to \mathcal{O}ut_s \mid \langle s_y, Sim_T(\mathcal{O}ut_s, In_s), s_x \rangle \} \]
  e.g., by suggesting \( \mathcal{H} \) to the end user as required information the composition process.

For instance

\[ \mathcal{H} := \inf \{ H_1, H_2, H_3, H_4, H_5 \} \]
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:
  \[ H := \inf \{ \text{Int}_s \cup \text{Out}_s \mid \langle s, \text{Sim}_T(\text{Out}_s, \text{Int}_s), s \rangle \} \]
  - e.g., by suggesting \( H \) to the end user as required information the composition process.

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- By relaxing some constraints during composition:
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- 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.
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?

![Diagram showing the computation of $\mathcal{H}$]
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.
Automated Computation of Robustness in Composition

Protocol for Robust Composition

1. 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.
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 Model

Quality Criteria for Semantic Links & Services

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

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

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

- 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: $\frac{1}{4}$).

<table>
<thead>
<tr>
<th>[ \text{size} ] refers to the size of $\mathcal{ALE}$ concept descriptions:</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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<tr>
<td>for instance $</td>
</tr>
</tbody>
</table>
Quality Criteria for Semantic Links & Services

\[ q(s_{l_{i,j}}) \text{ for Elementary Semantic Links } s_{l_{i,j}} \]

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

- **Matching Quality** \( q_m \in (0, 1] \), valued by \( Sim_T(Out_{s_i}, In_{s_j}) \)
  
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Quality Model

Quality Criteria for Semantic Links & Services

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

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

- Execution Price \( q_{pr} \in \mathbb{R}^+ \);
- Response Time \( q_t \in \mathbb{R}^+ \).
## Quality Criteria for Semantic Links & Services

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

- **Common Description rate** \( q_{cd} \in (0, 1] \):
  
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### \( q(s_i) \) 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 \( sl_{i,j} \)

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

---

**Diagram**

ABox $\mathcal{A}$

- $a : \text{Email}$
- $b : \text{PhoneNum}$
- $c : \text{ZipCode}$

Composition Goal

- Invoice

Semantic Link $sl_1$

- Email
- PhoneNum
- ZipCode

Semantic Link $sl_2$

- Email
- PhoneNum
- ZipCode

Semantic Link $sl_3$

- VideoDecoder
- Decoder
- PhoneNum

Semantic Link $sl_4$

- VoIPId
- IPAddress

Output Parameters of Web services

Input Parameters of Web services

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

Goal $\beta$

ABox $\mathcal{A}$

Valid Semantic Links
### Quality Aggregation Rules for Compositions

<table>
<thead>
<tr>
<th>Composition Construct</th>
<th>Quality Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Semantic</td>
</tr>
<tr>
<td></td>
<td>$Q_{cd}$</td>
</tr>
<tr>
<td>Sequential/AND-Branching</td>
<td>$\frac{1}{</td>
</tr>
<tr>
<td>OR-Branching</td>
<td>$\sum_{s_l} q_{cd}(s_l).p_{s_l}$</td>
</tr>
</tbody>
</table>

### Legend

- **Semantic Link $s_l$**
- **Input Parameter**
- **Output Parameter**

T: Task
s: Service

---

---
# Quality Model

## Quality Criteria for Composition

### Quality Aggregation Rules for Compositions

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- **Sequential/AND-Branching**
  - $\frac{1}{|sl|} \sum_{sl} q_{cd}(sl)$
  - $\prod_{sl} q_{m}(sl)$
  - $\frac{\sum_{s} q_{t}(s)}{\max_{s} q_{t}(s)}$
  - $\sum_{s} q_{pr}(s)$

- **OR-Branching**
  - $\sum_{sl} q_{cd}(sl).p_{sl}$
  - $\sum_{sl} q_{m}(sl).p_{sl}$
  - $\sum_{s} q_{t}(s).p_{s}$
  - $\sum_{s} q_{pr}(s).p_{s}$

### Legend
- **Semantic Link $sl$**
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Sequence

<table>
<thead>
<tr>
<th>$T_1$</th>
<th>$S_1$</th>
<th>$T_2$</th>
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<th>$T_3$</th>
<th>$S_3$</th>
<th>$T_4$</th>
<th>$S_4$</th>
<th>$T_5$</th>
<th>$S_5$</th>
<th>$T_6$</th>
<th>$S_6$</th>
<th>$T_7$</th>
<th>$S_7$</th>
<th>$T_8$</th>
<th>$S_8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$sl_{1,2}^1$</td>
<td>Network Connection</td>
<td>$sl_{2,3}^1$</td>
<td>Slow Network Connection</td>
<td>$sl_{3,5}^1$</td>
<td>$T_5$</td>
<td>$S_5$</td>
<td>$T_6$</td>
<td>$S_6$</td>
<td>$sl_{5,6}^1$</td>
<td>$T_7$</td>
<td>$S_7$</td>
<td>$T_8$</td>
<td>$S_8$</td>
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38/66
### Quality Criteria for Composition

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| Quality Aggregation Rules for Compositions: |

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  - $Q_{m}$: $\prod_{sl} q_{m}(sl)$

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**Legend**

- Semantic Link $sl$
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Quality Model

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A Quality Vector for Web Service Composition

“A” way to differentiate compositions:

$Q(c) \doteq (Q_{cd}(c), Q_m(c), Q_t(c), Q_{pr}(c))$
Computation of quality

- 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?

### Quality Model

**Your Turn!!!!**

#### Computation of quality

- Output Parameters of Web services
- Input Parameters of Web services
- Goal $\beta$
- ABox $\mathcal{A}$
- Valid Semantic Links

**Diagram:**

- $S_x$: Email, PhoneNumber, ZipCode
- $S_y$: Email, PhoneNumber, ZipCode
- $S_c$: XNetworkConnection FastNC
- $S_d$: VideoDecoder, Decoder
- $S_b$: VolPId, IPAddress

**Semantic Links:**

- $sl_1$: Email, PhoneNumber, ZipCode
- $sl_2$: XNetworkConnection SlowNC
- $sl_3$: VideoDecoder, Decoder
- $sl_4$: VolPId, IPAddress

**Goal:** Invoice

**ABox $\mathcal{A}$:**

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

$X \in \{\text{Slow}, \text{Fast}, \emptyset\}$
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., \(\frac{1}{|s_i^A|} \sum_{s_i^A} q_{ca}(s_i^A, j) \geq \nu, \ \nu \in [0, 1] \sum_{T_i} q_{pr}(T_i) \leq \nu, \ \nu \in \mathbb{R}^+\)

Main Goal to Achieve

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

Legend:
- $\text{Semantic Link } sl$
- $\rightarrow$ Input Parameter
- $\rightarrow$ Output Parameter
- $T$: Task
- $s$: Service

Complexity
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?
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.]
  *Artificial Intelligence: A Modern Approach.*

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) $f$-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
### 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 \(C_G\);

\[\frac{1}{|s|} \sum_{s, t} q_{ca}(s, t) \geq v, \ v \in [0, 1] \quad \sum_{T_i} q_{pr}(T_i) \leq v, \ v \in \mathbb{R}^+\]

- \(f\) 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** $sl_{i,j}^A$
- 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.
IP Based Approach

IP Based Global Selection

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).
**Introduction**

**Composability**

**Composition**

**Robustness**

**Quality**

**Evaluation**

**Conclusions**

---

**IP Based Approach**

### Objective Function

#### Step 1: Compositions Computation

Computation of $Q_{\lambda,1\leq\lambda\leq p}^{l,l\in\{r,cd,m\}}$, 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:

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

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

#### Step 3: Objective Function

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

Computing the scale-based compositions $Q_{l\in\{r,cd,m\}} \sim \lambda$.

What do you require to do this?

Goal $\beta$

ABox $\mathcal{A}$

Output Parameters of Web services

Input Parameters of Web services

Semantic Link $sl_1$ $\rightarrow$ XNetworkConnection $\rightarrow$ FastNC

Semantic Link $sl_2$ $\rightarrow$ XNetworkConnection $\rightarrow$ SlowNC

Semantic Link $sl_3$ $\rightarrow$ VideoDecoder $\rightarrow$ Decoder

Semantic Link $sl_4$ $\rightarrow$ VoIPId $\rightarrow$ IPAddress

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

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

$\vdash$ Valid Semantic Links

Goal $\beta$
An integer variable \( y_{i,j}^k \in \{0, 1\} \) for every candidate link \( s_{i,j}^k, 1 \leq k \leq n \) of an abstract link \( s_{i,j}^A \) indicates the selection or exclusion of link \( s_{i,j}^k \) in the IP problem.
IP Based Approach

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

T: Task
s: Candidate Service
Incompatibility Constraint

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

$$y_{i,j}^k + y_{j,\beta}^l \leq 1, \ \forall sl_{i,j}^A \ \forall sl_{j,\beta}^A$$
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).
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.
Modeling IP based Optimal Web Service Composition

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

\[ \text{Output Parameters of Web services} \quad \text{Input Parameters of Web services} \quad \text{ABox } \mathcal{A} \quad \text{Goal } \beta \quad \text{Valid Semantic Links} \]

\[ S_x, S_y \quad \text{A service such that } S_x, S_y \in \{S_a^-, S_a^+, S_a^+\} \]

Email
PhoneNum
ZipCode

X ∈ \{Slow, Fast, θ\}
Computational Complexity and Experimentation

### Computational Complexity
- The optimization problem is equivalent to an IP problem.
  \[ \Rightarrow \text{NP-hard!} \]

### Experimentation
- Exhaustive search based: High computation cost.
- IP based: Acceptable computation cost.
GA Based Approach

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: $f(c)$

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

- Operators on Genotypes: crossover, mutation, selection.
- Stopping Criterion: until the constraints are met!
Modeling GA Based Approach

Your Turn!!!!

Modeling GA based Optimal Web Service Composition

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

![Diagram showing task and service relationship]

T: Task  s: Service  Selected $s_i$ for $T_i$
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 $s_g$

$s_g := (A, \beta)$

Service Discovery and Selection
Impl: Naive

Repository of Semantic Web Services $S_{WS}^g$
Impl: jUDDI

Impl: WSML

Relevant Services $S_{WS}^g$

Not Found

Functional Level Composition
Impl: Java, perl-based Golog

Candidate Compositions $S_{WSC}$

Composition Optimization
Impl: CPLEX, Impl: JGAP-Lib

Services involved in Composition $S_{WSC}^g$

BPEL Rendering
Impl: Perl-based

Details
**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.
Industrial Scenarios in Use - An Example

Internet Package

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

Nowdays Solutions

- **Static/Predefined** packages.
  - $\text{ADSL Max}^+ + \text{HDTV}$.

Open Issue

- How to customize commercial offers in a **dynamic way**?
- The more offers the harder the composition task will be.
Experimentation

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>
<td>Nb services</td>
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</tr>
<tr>
<td>Semantic Links oriented</td>
<td>Nb Inputs, Outputs</td>
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<tr>
<td>Composition Optimization</td>
<td>Nb Services</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>Nb Candidate semantic Link</td>
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</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

1. Adding **Semantics** on Links;
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   - Coupling **Quality of Service** and **Semantic Links**;
   - Coupling Composition and Discovery.
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Thanks for your attention!

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