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SYSTEMATIC THOUGHT LEADERSHIP FOR INNOVATIVE BUSINESS

Web Service Behavior Matchmaking Using DL

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Background

Objectives

Modeling

Conclusion

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Industry Needs

- Dynamic markets → Demand business **flexibility & interoperability**

Solution: Web Services

- Define software components using **standardized** interface language
- WSDL: **Inputs & outputs** – Business processes: Demand **behavior**

Semantic Web Service Approaches

- Integrate many aspects (eg. inputs, outputs, behavior)
- Rich constructs (eg. subclasses, subproperties, quantifiers, restrictions)
- Powerful reasoner (consistency, subsumption, instance classification)
- Do not leverage standard reasoning for main tasks (eg. matchmaking)

Contribution

- Describe Web services behavior by *description logic* (DL) expressions
- Formulate DL expressions in a way that reasoner can do matchmaking



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Web Service Behavior

■ Explanation

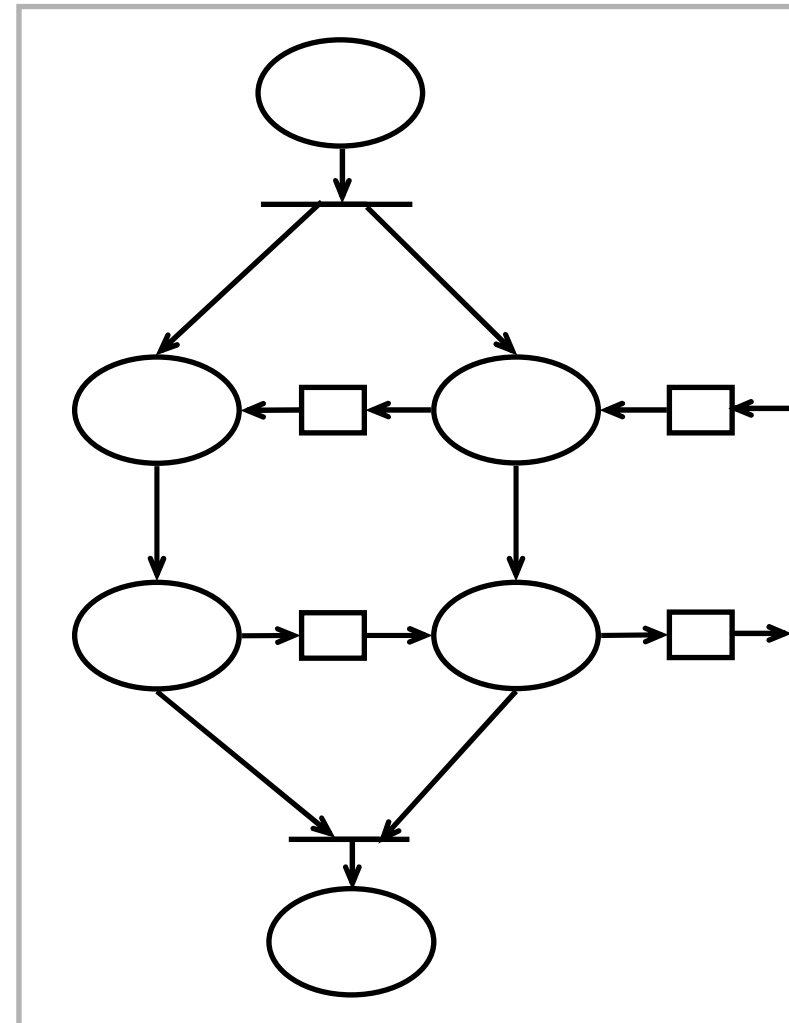
- ◆ Causal constraints between operations
- ◆ Required for successful invocation

■ Constituents

- ◆ Inputs
- ◆ Outputs
- ◆ Sequence
- ◆ Fork & Join
- ◆ Decision & Merge
- ◆ Other complex patterns

➔ Web service behavior as workflow

- ◆ Cp. YAWL
- ◆ Cp. UML v2.0 activity diagrams



Objectives – Requests vs. Services

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Use Case

- Existing business process
- Outsourcing of one step
- Find a new service fitting the hole the removed service left behind

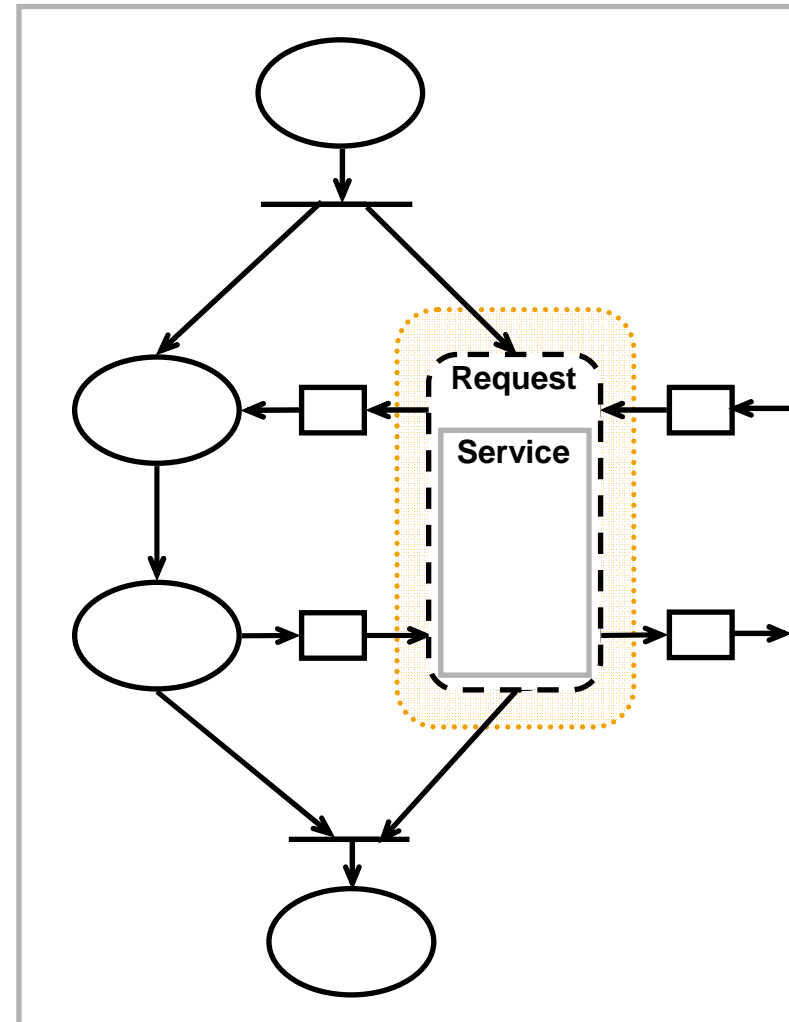
Request

- Defines indispensable constraints
- All possibilities must be followed

Service

- Defines all possible interactions
- Must be able to follow all possible interactions offered

➔ Examples to follow...



Objectives – Inputs vs. Outputs

Use Case

- Outsourcing of one process step
- Find services that **only** take provided inputs while serving **all** required outputs

Inputs

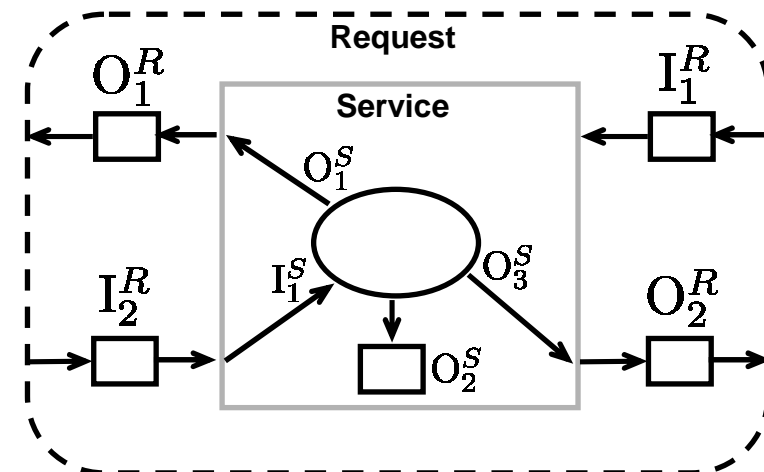
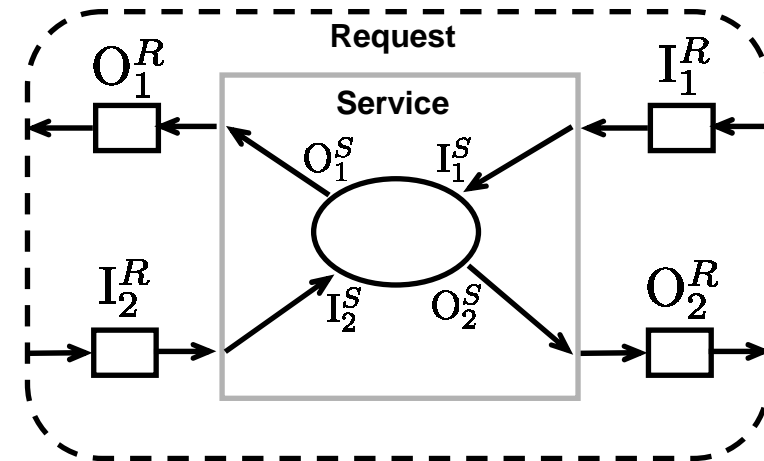
$$|I_R| \geq |I_S|$$

- Request I_R
 - ◆ Inputs that can be used
- Service I_S
 - ◆ Inputs that are required

Outputs

$$|O_R| \leq |O_S|$$

- Request O_R
 - ◆ Outputs that are required
- Service O_S
 - ◆ Outputs that can be used





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Inputs (repeated)

$$|I_R| \geq |I_S|$$

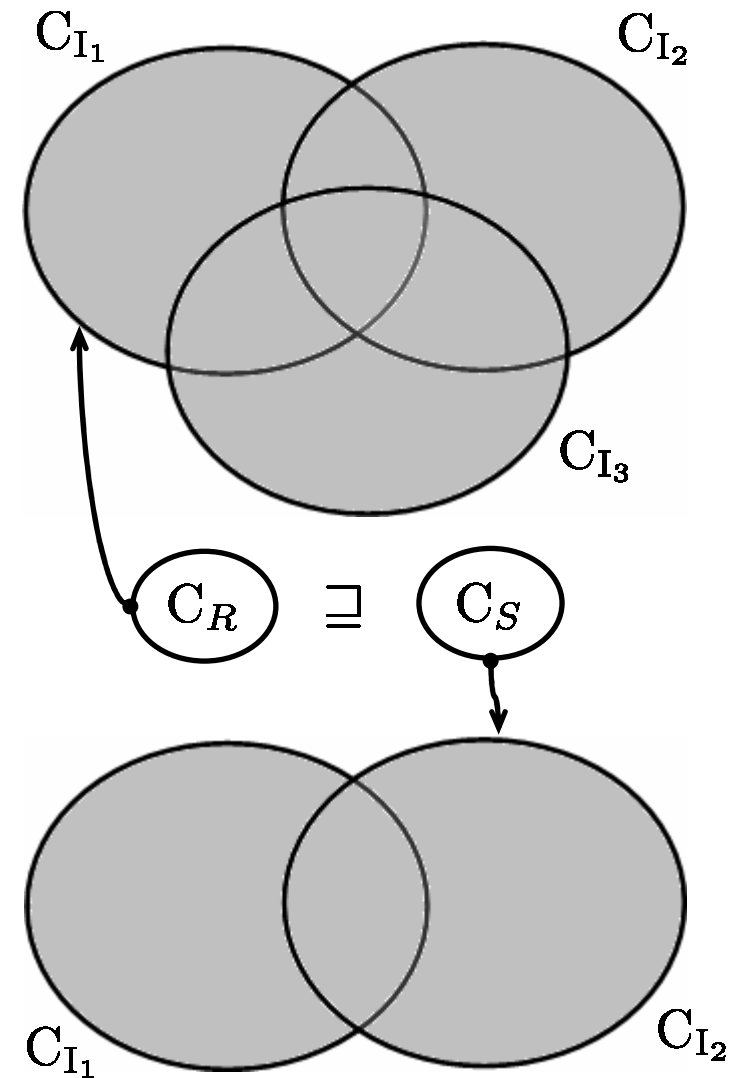
- Request I_R
 - ◆ Inputs that can be used
- Service I_S
 - ◆ Inputs that are required

Implementation

- $I_R = \{ I_1^R, I_2^R, \dots, I_m^R \}$
- $C_R \equiv \exists \text{ has. } (C_{I_1^R} \sqcup C_{I_2^R} \sqcup \dots \sqcup C_{I_k^R})$
- $I_S = \{ I_1^S, I_2^S, \dots, I_n^S \}$
- $C_S \equiv \exists \text{ has. } (C_{I_1^S} \sqcup C_{I_2^S} \sqcup \dots \sqcup C_{I_l^S})$

Analysis

- Check for $C_R \sqsupseteq C_S$



Outputs (repeated)

$$|O_R| \leq |O_S|$$

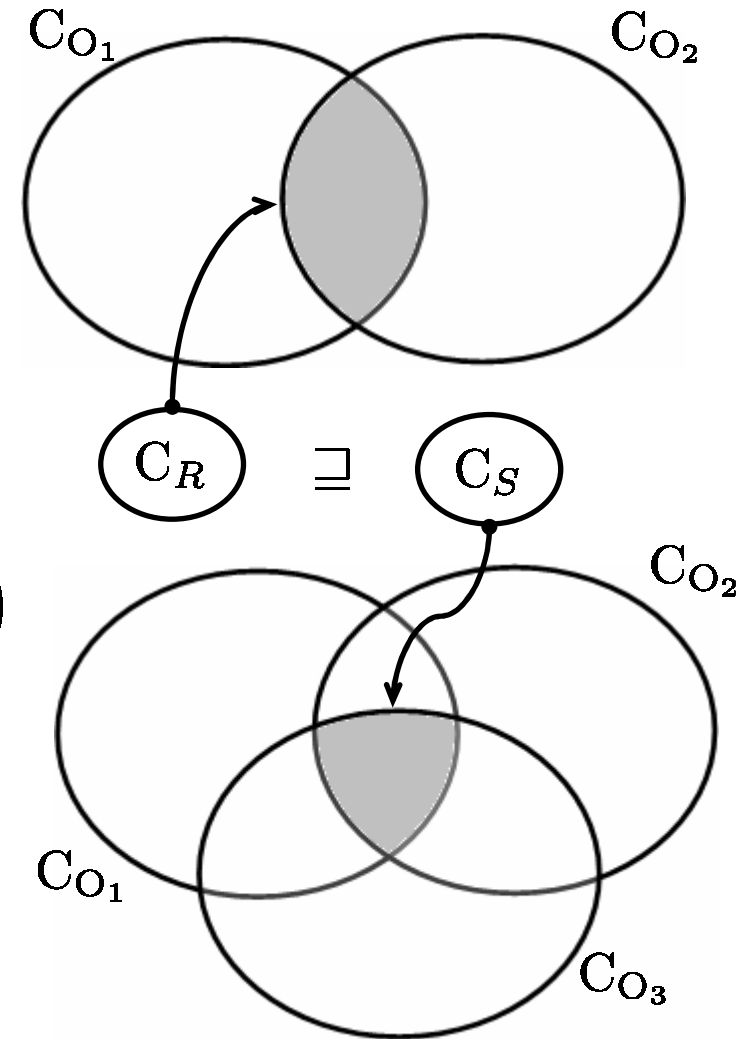
- Request O_R
 - ◆ Outputs that are required
- Service O_S
 - ◆ Outputs that can be used

Implementation

- $O_R = \{O_1^R, O_2^R, \dots, O_m^R\}$
- $C_R \equiv \exists \text{ has. } (C_{O_1^R} \sqcap C_{O_2^R} \sqcap \dots \sqcap C_{O_m^R})$
- $O_S = \{O_1^S, O_2^S, \dots, O_n^S\}$
- $C_S \equiv \exists \text{ has. } (C_{O_1^S} \sqcap C_{O_2^S} \sqcap \dots \sqcap C_{O_n^S})$

Analysis

- Check for $C_R \sqsupseteq C_S$



Implementation

$$|I_R| \geq |I_S|$$

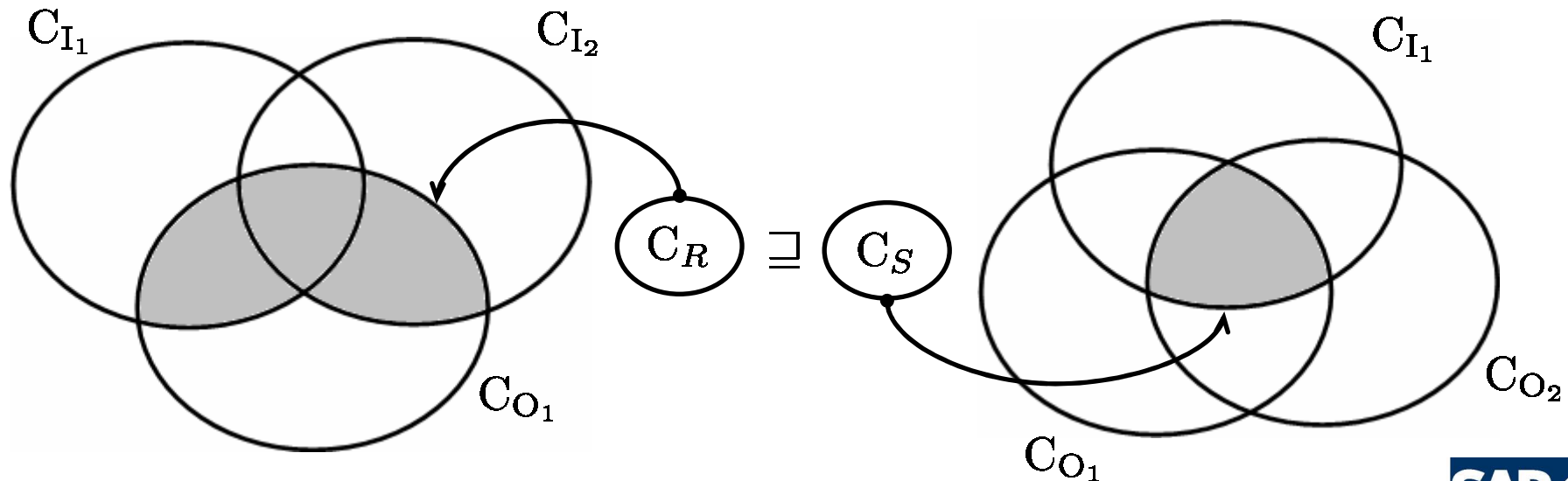
$$|O_R| \leq |O_S|$$

■ $IO_R = I_R \cup O_R$

→ $C_R \equiv \exists \text{ has. } \left[\left(C_{I_1^R} \sqcup C_{I_2^R} \sqcup \dots \sqcup C_{I_k^R} \right) \sqcap \left(C_{O_1^R} \sqcap C_{O_2^R} \sqcap \dots \sqcap C_{O_m^R} \right) \right]$

■ $IO_S = I_S \cup O_S$

→ $C_S \equiv \exists \text{ has. } \left[\left(C_{I_1^S} \sqcup C_{I_2^S} \sqcup \dots \sqcup C_{I_i^S} \right) \sqcap \left(C_{O_1^S} \sqcap C_{O_2^S} \sqcap \dots \sqcap C_{O_n^S} \right) \right]$



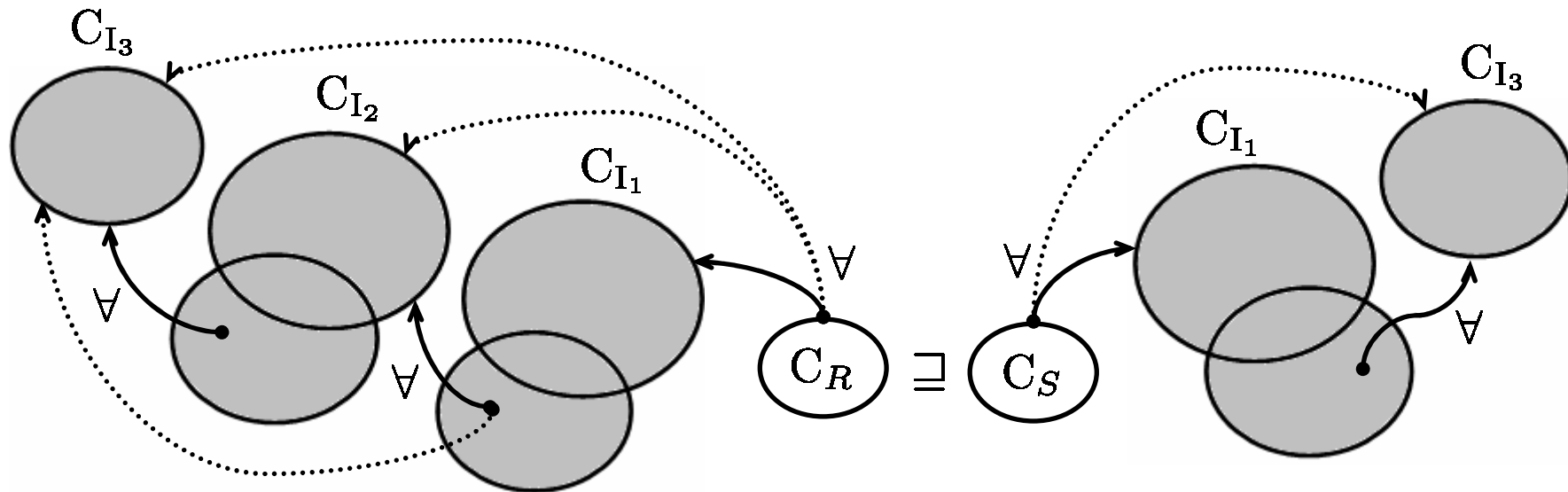
Implementation

$$|I_R| \geq |I_S|$$

■ transitive (then)

■ $\text{Seq}^I = I_1 \mapsto I_2 \mapsto \dots \mapsto I_k$

→ $C \equiv \exists \text{ has. } [(C_{I_1} \sqcup C_{I_2} \sqcup \dots \sqcup C_{I_k})$
 $\sqcap (\forall \text{ then. } (C_{I_1} \sqcup \forall \text{ then. } (C_{I_2} \sqcup \forall \text{ then. } (\dots \sqcup \forall \text{ then. } C_{I_k})))))]$



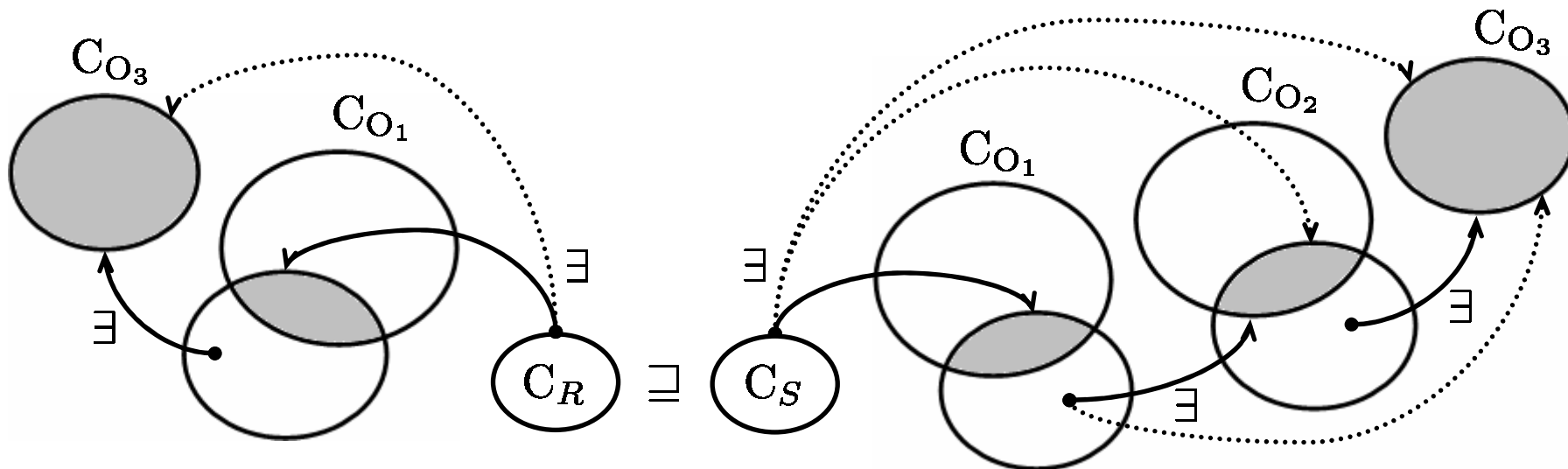
Implementation

$$|O_R| \leq |O_S|$$

■ transitive (then)

■ $\text{Seq}^O = O_1 \mapsto O_2 \mapsto \dots \mapsto O_m$

→ $C \equiv \exists \text{ has. } [(C_{O_1} \sqcap C_{O_2} \sqcap \dots \sqcap C_{O_m})$
 $\sqcap (\exists \text{ then. } (C_{O_1} \sqcap \exists \text{ then. } (C_{O_2} \sqcap \exists \text{ then. } (\dots \sqcap \exists \text{ then. } C_{O_m})))))]$



Implementation

$$|I_R| \geq |I_S|$$

$$|O_R| \leq |O_S|$$

- transitive (then)
- $\text{Seq}^{\text{IO}} = X_1 \mapsto X_2 \mapsto \dots \mapsto X_m$, where $X \in \{I, O\}$
- $C \equiv \exists \text{ has. } [(C_{I_1} \sqcup C_{I_2} \sqcup \dots \sqcup C_{I_k}) \sqcap (C_{O_1} \sqcap C_{O_2} \sqcap \dots \sqcap C_{O_l})$
 $\sqcap (\Omega_1 \text{ then. } (C_{X_1} \Delta_1 \Omega_2 \text{ then. } (C_{X_2} \Delta_2 \Omega_3 \text{ then}$
 $\text{. } (\dots \Delta_{m-1} \Omega_m \text{ then. } C_{X_m} \text{)))]]$

$$\text{where } \Omega_i = \begin{cases} \forall, & C_{X_i} = C_{I_i} \\ \exists, & C_{X_i} = C_{O_i} \end{cases} \quad k + l = m$$

$$\text{and } \Delta_i = \begin{cases} \sqcup, & C_{X_i} = C_{I_i} \\ \sqcap, & C_{X_i} = C_{O_i} \end{cases} \quad 1 \leq i \leq m$$

→ Example to follow...

Example

- **Request** $\text{Ordering}^{\text{IO}} = \text{login}^{\text{I}} \mapsto \text{order}^{\text{I}} \mapsto \text{userData}^{\text{I}} \mapsto \text{conf}^{\text{O}}$
- **Services**
 - $\text{Store}^{\text{IO}} = \text{login}^{\text{I}} \mapsto \text{wMsg}^{\text{O}} \mapsto \text{order}^{\text{I}} \mapsto \text{conf}^{\text{O}}$
 - $\text{Fraud}^{\text{IO}} = \text{userData}^{\text{I}} \mapsto \text{login}^{\text{I}} \mapsto \text{order}^{\text{I}} \mapsto \text{conf}^{\text{O}}$

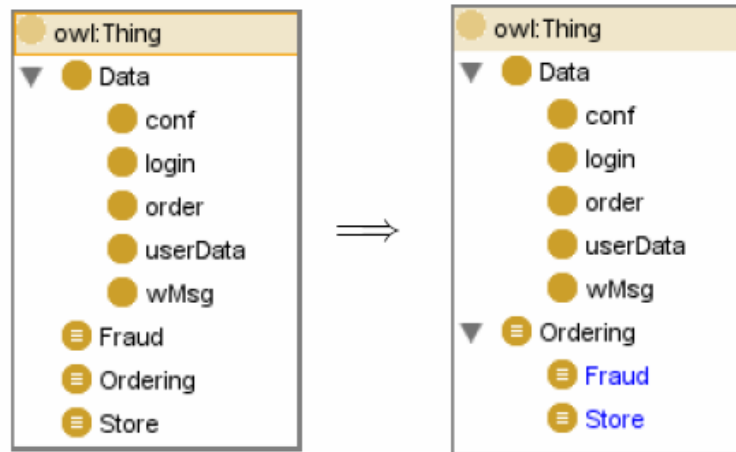


Fig. 1. Inference considering Interactions

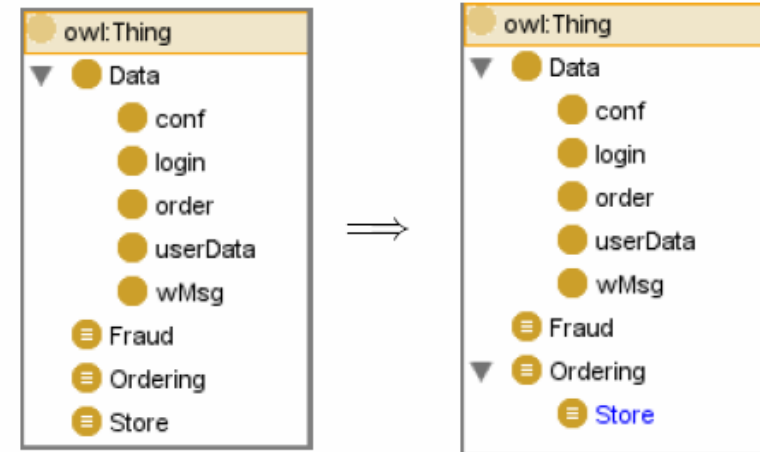


Fig. 2. Inference considering Behavior



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Summary

- **DL models for service interactions**
 - ◆ **Correct and complete if not otherwise stated**

- **Restricting inputs**
- **Requiring outputs**
- **Restricting inputs and requiring outputs**

- **Sequence of inputs**
- **Sequence of outputs**
- **Sequence of mixed inputs and outputs**
 - ◆ **Correct (matches returned are never wrong)**
 - ◆ **Not complete (does not find all possible matches)**

Features

- **Robustness** – Facilitation of existing reasoner component
- **Integrability** – Can reference other semantic Web resources
- **Extendability** – Easily extendable by other facets of Web services

Limitations

- **At least one input and output, respectively**
- **No disjoint concepts allowed**
- **Expressivity**

Open Questions

- **Complex interaction patterns (eg. fork, decision, loop)**
- **Proof of properties (eg. correctness & completeness)**
- **Comparison with other “dynamic” approaches (eg. petri nets)**



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Thank you

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