5th International Semantic Service Selection Contest
– Performance Evaluation of Semantic Service Matchmakers –

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Outline

- Semantic Selection
- Evaluation Framework
- Evaluation Results & Lessons Learned

Semantic Service Selection

- **Service discovery**
  - Centralized in Web service registries (W3C SOA) or with search engines
  - Decentralized in P2P service networks

- **Semantic selection** (aka semantic matchmaking)
  1. Semantic matching of registered services $S$ with desired service description $Q$
  2. Relevance ranking of $S$ (answer set) for final selection of services by user

NO brokerage (composition, publish/subscribe negotiation, execution handling)

Shared ontology KB for semantic annotation: In/Out, Non-func params

Match($S, Q, KB$)
Evaluation of Semantic Selection

(1) Support of service description languages
   - OWL-S, WSML, SAWSDL, SA-REST, USDL, hRESTS
   - Agnostic: Semantic-preserving transformations, metamodels

(2) Support of composition
   - Pruning of composition search space by selection
   - Iterative selection for forward/backward chaining

(3) Security (data privacy)

(4) Usability and configuration efforts

(5) Performance of selection
   Correctness:  Precision, Recall, MAP, F1, etc.
   Speed:        Average query response time
### Other Evaluation Initiatives

- Comparison with other service evaluation initiatives:

<table>
<thead>
<tr>
<th></th>
<th>SWS Challenge</th>
<th>WS Challenge</th>
<th>S3 Contest</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scope</strong></td>
<td>composition</td>
<td></td>
<td>discovery</td>
</tr>
<tr>
<td></td>
<td>(given scenarios)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>-</td>
<td>runtime</td>
<td>IR measures, runtime</td>
</tr>
<tr>
<td><strong>Usability/effort</strong></td>
<td>adaptation effort</td>
<td>-</td>
<td>description effort</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(cross-eval track in 2009)</td>
</tr>
<tr>
<td><strong>Correctness</strong></td>
<td>Alg. correctness</td>
<td></td>
<td>Retrieval correctness</td>
</tr>
</tbody>
</table>

Participants of S3 Contest 2012

Track 1  OWL-S Service Matchmakers

1. iSeM 1.1 (DFKI, Germany)
2. OWLS-MX3 (DFKI, Germany)
3. SeMa\textsuperscript{2} v2 (TU Berlin, Germany)
4. Nuwa-OWLS (URJC Madrid, Spain)
5. OWLS-iMatcher (U Zurich, Switzerland)
6. SPARQLent (HP, Italy)
7. OWLS-SLR (Aristotle U of Thessaloniki, Greece)
8. XSSD (Beihang U, China)
9. EMMA (U Seville, Spain)
10. iSeM-TSM1 (Payame Noor U, Iran / DFKI)
Service Selection By Participants in Brief

- iSeM 1.1
  - Selection: Hybrid; Signature (I/O), Specification (P/E), Service description tag
    - Logic-based matching
      - Logical I/O concept subsumption + information-theoretic valuation of approximated logical I/O concept subsumption
      - Logical P/E plugin checking (theta-subsumption)
    - Non-logic-based matching
      - Text similarity of unfolded service signatures (I/O) and service description tags,
      - Ontology-based structural I/O match - Separated filters
    - Adaptive (offline): SVM relevance classifier with coherence-based weighting scheme
      [TS = 5% OWLS-TC4] for aggregation of matching degrees with subsequent ranking
  - Dev: Patrick Kapahnke, Matthias Klusch (DFKI, Germany), 2010
Service Selection By Participants in Brief

- **iSeM-TSM1**

  Selection: *Non-logic-based; Signature (I/O), Service description tag*

  - Non-logic-based matching
    - Text similarity of unfolded service signatures (I/O) and service description tags,
    - Ontology-based structural I/O match - Separated filters

  - Dev: Elyad Alaei, Ahmad Faraahi (Payame Noor U, Iran),
    Mohammad-Reza Feizi-Derakhshi (U Tabriz, Iran)
Selection: *Hybrid; Signature (I/O), Service description text*

- **Logic-based matching:** Logical concept subsumption
- **Non-logic-based matching:**
  - Ontology-based (WordNet) structural I/O concept label match
    (I/O concept label e.g. [http://foo/bar.owl#door](http://foo/bar.owl#door) --> label: “door“)
  - Text similarity (Cosine TF-IDF) of keywords extracted from:
    Semantic I/O concept URI fragments, labels
    Service textual description
    Service name and service URI fragment
- **Ranking:** Weighted sum of results of both matching types

Dev: Zije Cong, Alberto Fernandez (URJC Madrid, Spain)
Service Selection By Participants in Brief

- **SeMa² v2**
  
  - Selection: *Hybrid; Signature (I/O), Specification (P/E)*
  
  - **Logic-based matching:**
    
    - Logical I/O concept subsumption relation as numeric score
    - Logical P/E (SWRL rule) plugin matching with theta-subsumption (no ABox) + separated precondition checking over given ABox

  - **Non-logic-based matching:**
    
    - String matching of I/O concept names (string.equal() / .contains())
    - Structural and taxonomic matching of variable types in SWRL (P/E) rules

- **Ranking:** Linear weighted aggregation of all matching scores

- Dev: Nils Masuch (TU Berlin, Germany)
Service Selection By Participants in Brief

- **OWLS-SLR lite**
  - Selection: *Hybrid; Signature (I/O)*, *Non-functional parameters*
    - **Logic-based match:** Logical I/O concept subsumption relations as basis for ...
    - **Non-logic-based match:** ... Ontology-based structural match (edge distance, upward co-topic distance)
  - **Ranking:** Structural similarity
  - Dev: Georgios Meditskos, Nick Bassiliades (U Thessaloniki, Greece)

- **OWLS-iMatcher**
  - Selection: *Syntactic; Signature (I/O)*
    - **Non-logic-based:** Vector-based text similarities of unfolded service signatures
    - **Ranking:** Text similarity
  - Dev: Christoph Kiefer, Avi Bernstein (U Zurich, Switzerland)
Service Selection By Participants in Brief

- **OWLS-MX3**
  - Selection: *Hybrid, adaptive; Signature (I/O)*
    - Logic-based match: Logical I/O concept subsumption
    - Non-logic-based match: Text similarity of unfolded service signatures, Ontology-based structural match - Separated filters
    - Adaptive (offline): SVM relevance classifier [TS = 10% OWLS-TC3] for aggregation of (non-)logic-based matching degrees with subsequent ranking
  - Dev: Matthias Klusch, Patrick Kapahnke (DFKI, Germany)

- **SPARQLent**
  - Selection: *Logic-Based; Signature (I/O), Specification (P/E)*
    - Logic-based match: P/E described in SPARQL, I/O concepts represented as additional constraints; I/O concept match via RDF entailment rules for RDF-encoded OWL
  - Dev: Marco Luca Sbodio (Hewlett-Packard EIC, Italy)
Service Selection By Participants in Brief

- **XSSD**
  - Selection: *Hybrid; Signature (I/O), Service description tag*
    - **Logic-based match:** Logical I/O concept subsumption
    - **Non-logic-based match:** Text similarity match of service description tags
    - **Ranking:** Logic-based degree followed by text similarity-based ranking
  - Dev: Jing Li, Dongjie Chu (U Beihang, China)

- **EMMA**
  - Selection: *Logic-based semantic pre-filtering; Signature (I/O)*
    - **Logic-based pre-filtering:** SPARQL query in Jena RDF store using inference rules
    - **Hybrid match:** Based on pre-filtering using OWLS-MX3 (or other OWL-S MM plugins)
    - **Ranking:** Ranking procedure of internal OWLS-MX3 plugin
  - Dev: José María García, David Ruiz, Antonio Ruiz-Cortés (U Seville, Spain)
Participants of S3 Contest 2012

**Track 2**  SAWSDL Service Matchmakers

1. LOG4SWS.KOM (TU Darmstadt, Germany)
2. COV4SWS.KOM (TU Darmstadt, Germany)
3. iSeM 1.1 (DFKI, Germany)
4. SAWSDL-MX1 (DFKI, Germany)
5. URBE (Politecnico di Milano, Italy)
6. SAWSDL-iMatcher (U Zurich, Switzerland)
7. Nuwa-SAWSDL (URJC Madrid, Spain)
Service Selection By Participants

- **LOG4SWS.KOM**
  - Selection: *Hybrid; Signature (I/O), Element names*
    - **Logic-based match:** Logical I/O concept subsumption relation as numeric score
    - **Non-logic-based match:** Ontology-based structural I/O concept similarity (path length); WordNet distance (fallback strategy for missing modelReference)
    - **Adaptive (offline):** Aggregated results using Ordinary Least Squares (OLS)
    - **Ranking:** Linear weighted average similarity of matched operations

- **COV4SWS.KOM**
  - Selection: *Non-logic-based (see LOG4SWS.KOM); Signature (I/O), Element names*

Dev: Stefan Schulte, Ulrich Lampe (TU Darmstadt, Germany)
Service Selection By Participants

• **URBE**
  - Selection: *Non-logic-based; Signature (I/O)*
    - Non-logic-based match: Bipartite graph-matching of service operations; Ontology-based structural I/O concept similarity (worst-case path length in given reference ontology); Text similarity (WordNet) for property-class and XSD data type matching
  - **Ranking:** Weighted aggregation of structural and text matching scores

Dev: Pierluigi Plebani (Politecnico di Milano, Italy)

• **SAWSDL-MX1**
  - Selection: *Hybrid; Signature (I/O)*
    - Logic-based match: Logical I/O concept subsumption
    - Non-logic-based match: Text similarity of unfolded concept definitions
    - **Ranking:** Logic-based sorted by text similarities

Dev: Patrick Kapahnke, Matthias Klusch (DFKI, Germany)
• **SAWSDL-iMatcher**
  - Selection: *Non-logic-based; Signature (I/O)*
    - *Non-logic-based*: Vector-based text similarities of unfolded service signatures
    - *Ranking*: Text similarity

Dev: Dengping Wei, Avi Bernstein (U Zurich, Switzerland)

• **iSeM 1.1 for SAWSDL**
  - Selection: *Hybrid; Signature (I/O), Service name*
    - *Match*: [cf. iSeM 1.1 for OWL-S, slide 7]
      but no P/E match; uses service name instead of description tag

• **Nuwa-OWLS**
  - Selection: *Hybrid; Signature (I/O), Service description text*
Classification

• Tracks [#participants]
  - OWL-S [11]
  - SAWSDL [7]
  - hREST/WSML-lite [2]
  - Others [3]
Framework Components in Brief

- **Service retrieval test collections**
  - **Track1:** OWLS-TC 4.0
    - 1.083 services, 42 requests w/ binary & graded relevance sets, 38 ontologies
    - Groundings in WSDL 1.1, 7 domains (Communication, Economy, Education, Food, Medical Care, Travel, Military)
    - 160 services and 18 requests w/ preconditions + effects each in SWRL and PDDL2
    - @semwebcentral: 14.339 downloads (in Top-10 as of March 7, 2012)
  - **Track2:** SAWSDL-TC 3.0
    - 1.080 services, 42 requests w/ binary & graded relevance sets, 38 ontologies
    - @semwebcentral: 760 downloads (March 7 2012)
  - **Track3:** hRESTS 1.0
    - Development: DFKI, U Jena, TU Darmstadt, U Beihang, U Thessaloniki, a.o.

- **Evaluation tool:** SME² v2.2
  - Open source publicly available @semwebcentral.org since 2008: 2.816 downloads (March 7 2012)
  - Plugin interface for contested matchmakers; standard retrieval performance measures
### Service Relevance

- **Relevance assessment of services**
  - Binary relevance value: Relevant (1), or Irrelevant (0)
  - Standard NTCIR 4-graded relevance scale used @TREC:

<table>
<thead>
<tr>
<th>Relevance Grade</th>
<th>Gain value</th>
<th>Intuitive Meaning of Relevance Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly relevant</td>
<td>3</td>
<td>„Perfectly satisfies request ( S \equiv R )“</td>
</tr>
<tr>
<td>Relevant</td>
<td>2</td>
<td>„Relevant to request with some conditions of its conditions not satisfied ( S \subset R )“</td>
</tr>
<tr>
<td>Partially relevant</td>
<td>1</td>
<td>„Helpful to satisfy request by providing related information ( S \cap R \neq \emptyset, S \not\subset R )“</td>
</tr>
<tr>
<td>Not Relevant</td>
<td>0</td>
<td>„Not relevant at all ( S \cap R = \emptyset )“</td>
</tr>
</tbody>
</table>

- Relevance sets defined by **union average pooling** of assessments:
  - >> Service relevant if judged relevant by *at least one* user (TREC).
  - >> Services not yet rated, or not in relevance set are irrelevant.
**Evaluation Tool SME\(^2\) v2.2**

**Performance measures**

- Macro-averaged precision@recall MAP
- Average precision AP
- Q, nDCG [Graded relevance]
- Average query response time AQRT (elapsed time per query execution)
- http-request analysis
- Precision@k, R-Precision

**Easy handling**

→ Load test collections +
   Select matchmaker plugin(s) +
   Configure evaluation run
→ Tailor your (printable) report of evaluation results
Evaluation Tool SME² v2.2

Implementation
- Plug-in architecture
- Implemented in Java
- XML-based matchmaker plugin & TC configuration
- Jetty web server embedded

Developed @ DFKI:
Minko Dudev
Patrick Kapahnke
Josef Misutka
Martin Vasileski
Matthias Klusch
Outline

- Semantic Selection
- Evaluation Framework
- Evaluation Results & Lessons Learned
## OWL-S Selection: Average Precision (Bin)

<table>
<thead>
<tr>
<th>Matchmaker</th>
<th>AP</th>
<th>Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. iSeM 1.1</td>
<td>.922</td>
<td>DFKI, Germany</td>
</tr>
<tr>
<td>2. SeMa² v2</td>
<td>.877</td>
<td>TU Berlin, Germany</td>
</tr>
<tr>
<td>3. iSeM-TSM1</td>
<td>.861</td>
<td>Payame Noor U, Iran / DFKI</td>
</tr>
<tr>
<td>4. Nuwa-OWLS</td>
<td>.853</td>
<td>URJC Madrid, Spain</td>
</tr>
<tr>
<td>5. OWLS-MX3</td>
<td>.831</td>
<td>DFKI, Germany</td>
</tr>
<tr>
<td>6. XSSD</td>
<td>.795</td>
<td>U Beijing, PR China</td>
</tr>
<tr>
<td>7. EMMA</td>
<td>.762</td>
<td>U Seville, Spain</td>
</tr>
<tr>
<td>8. OWLS-iMatcher</td>
<td>.672</td>
<td>U Zurich, Switzerland</td>
</tr>
<tr>
<td>9. SPARQLent</td>
<td>.612</td>
<td>HP, Italy</td>
</tr>
<tr>
<td>10. OWLS-SLR (lite)</td>
<td>.609</td>
<td>Aristotle U, Greece</td>
</tr>
</tbody>
</table>

Please note: For matchmakers with more than one variant, the one with best AP is shown.
OWL-S Selection: Macro-Averaged Precision for Binary Relevance

Recall/Precision (macro-averaged)

OWLS-iMatcher (8.)
EMMA (7.)
SPARQLent (9.)
OWLS-SLR (10.)
iSeM (1.)
## OWL-S Selection: Average Precision (Grad)

<table>
<thead>
<tr>
<th>Matchmaker</th>
<th>AP: nDCG</th>
<th>Matchmaker</th>
<th>AP: Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SeMa² v2</td>
<td>.927</td>
<td>1. SeMa² v2</td>
<td>.883</td>
</tr>
<tr>
<td>2. iSeM-TSM1</td>
<td>.916</td>
<td>2. iSeM-TSM1</td>
<td>.855</td>
</tr>
<tr>
<td>4. OWLS-MX3</td>
<td>.899</td>
<td>4. OWLS-MX3</td>
<td>.834</td>
</tr>
<tr>
<td>5. XSSD</td>
<td>.881</td>
<td>5. iSeM 1.1</td>
<td>.821</td>
</tr>
<tr>
<td>6. EMMA</td>
<td>.87</td>
<td>6. EMMA</td>
<td>.7884</td>
</tr>
<tr>
<td>7. iSeM 1.1</td>
<td>.841</td>
<td>7. XSSD</td>
<td>.7881</td>
</tr>
<tr>
<td>8. SPARQLent</td>
<td>.728</td>
<td>8. OWLS-iMatcher</td>
<td>.671</td>
</tr>
<tr>
<td>9. OWLS-SLR (lite)</td>
<td>.723</td>
<td>9. SPARQLent</td>
<td>.576</td>
</tr>
<tr>
<td>10. OWLS-iMatcher</td>
<td>.719</td>
<td>10. OWLS-SLR (lite)</td>
<td>.57</td>
</tr>
</tbody>
</table>
Lesson Learned: Specification Matching

Only very few matchmakers perform specification (P/E) matching

- **SeMa² v2** (TU Berlin)
  
  - Structural + logical plugin (no Abox) + precondition satisfaction (ABox)
- **SPARQLent** (HP Italy)
  
  - SPARQL ASK [where] query containment (ABox)
- **iSeM 1.1** (DFKI)
  
  - Logical plugin (no Abox)

Current problems:

- Test collection OWLS-TC has no ABoxes
- P/E in PDDL and SWRL: SWRL syntax in OWL-S spec and SWRL spec differ
Lesson Learned: Specification Matching

Problems

- Only 15% of OWLS-TC4 services have P/Es. Low increase of precision with P/E match.
- „Solution“ of I/O pitfalls by „luck of random choice“ (S1 or S2) w/o PE matching
- Collections require more services with (complex) P/E descriptions

Example:

<table>
<thead>
<tr>
<th>Rank</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TP</td>
<td>TP</td>
<td>FP</td>
<td>-</td>
</tr>
<tr>
<td>iSeM 1.0</td>
<td>IOPE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OWLS-SLR</td>
<td>TP</td>
<td>FP</td>
<td>TP</td>
<td>FP</td>
</tr>
<tr>
<td>SeMa2</td>
<td>TP</td>
<td>FP</td>
<td>FP</td>
<td>TP</td>
</tr>
<tr>
<td>XSSD</td>
<td>TP</td>
<td>FP</td>
<td>TP</td>
<td>FP</td>
</tr>
</tbody>
</table>

![Graph showing Recall/Precision (macro-averaged)](image)

- iSeM w/o PE matching
  - $\Delta AP = 0.068$ significant at 5%
  - $\Delta Q = 0.062$ significant at 5%
  - $\Delta nDCG = 0.059$ significant at 5%
## OWL-S Selection: Average Response Time

<table>
<thead>
<tr>
<th>Matchmaker</th>
<th>AQRT (s)</th>
<th>w/o http</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. XSSD</td>
<td>0.125</td>
<td>0.124</td>
</tr>
<tr>
<td>2. OWLS-SLR lite</td>
<td>0.46</td>
<td>0.446</td>
</tr>
<tr>
<td>3. SPARQLent</td>
<td>0.576</td>
<td>0.569</td>
</tr>
<tr>
<td>4. OWLS-iMatcher</td>
<td>2.152</td>
<td>2.121</td>
</tr>
<tr>
<td>5. iSeM 1.1</td>
<td>2.34</td>
<td>2.332</td>
</tr>
<tr>
<td>6. iSeM-TSM1</td>
<td>4.447</td>
<td>4.437</td>
</tr>
<tr>
<td>7. OWLS-MX3</td>
<td>5.369</td>
<td>4.997</td>
</tr>
<tr>
<td>8. SeMa² v2</td>
<td>5.084</td>
<td>5.063</td>
</tr>
<tr>
<td>9. EMMA</td>
<td>9.644</td>
<td>9.335</td>
</tr>
</tbody>
</table>

Vs. fastest variant

[|AQRT; diff AP|]: diff rank AQRT

Repeated restart of plugin!
Lessons Learned: Caching Strategies

OWL-S matchmakers deal with required service ontologies quite differently

- **Caching of complete ontologies during service registration**
  - Reduces #http-requests: Only queries but no ontology d/l required for Q/A
  - Used by XSSD, OWLS-iMatcher, SeMa²

- **Caching of self-contained (unfolded) concept definitions**
  - Reduces #http-requests: No additional classification of concepts required for Q/A
  - Used by iSeM 1.1 (and iSeM-TSM1), OWLS-MX3

- **No caching at all**
  - EMMA - restarts internally used pugin for every query
<table>
<thead>
<tr>
<th>Matchmaker</th>
<th>AP (B)</th>
<th>AP (G): nDCG, Q</th>
<th>Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. iSeM 1.1</td>
<td>.842</td>
<td>.803, .762</td>
<td>DFKI, Germany</td>
</tr>
<tr>
<td>2. LOG4SWS.KOM</td>
<td>.837</td>
<td>.896, .851</td>
<td>TU Darmstadt, Germany</td>
</tr>
<tr>
<td>3. COV4SWS.KOM</td>
<td>.823</td>
<td>.884, .825</td>
<td>TU Darmstadt, Germany</td>
</tr>
<tr>
<td>4. Nuwa-SAWSDL</td>
<td>.819</td>
<td>.884, .817</td>
<td>URJC Madrid, Spain</td>
</tr>
<tr>
<td>5. SAWSDL-iMatcher</td>
<td>.764</td>
<td>.855, .784</td>
<td>U Zurich, Switzerland</td>
</tr>
<tr>
<td>6. URBE</td>
<td>.749</td>
<td>.85, .777</td>
<td>Politecnico Milano, Italy</td>
</tr>
<tr>
<td>7. SAWSDL-MX1</td>
<td>.747</td>
<td>.839, .767</td>
<td>DFKI, Germany</td>
</tr>
</tbody>
</table>
SAWSDL Selection: Macro-Averaged Precision for Binary Relevance

Recall/Precision (macro-averaged)

- LOG4SWS (2.)
- URBE (6.)
- SAWSDL-MX1 (7.)
- iSeM (1.)
## SAWSDL Selection: Average Response Time

<table>
<thead>
<tr>
<th>Matchmaker</th>
<th>AQRT (s)</th>
<th>w/o http</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. LOG4SWS.KOM</td>
<td>0.241</td>
<td>0.241</td>
</tr>
<tr>
<td>2. COV4SWS.KOM</td>
<td>0.301</td>
<td>0.301</td>
</tr>
<tr>
<td>3. SAWSDL-iMatcher</td>
<td>1.787</td>
<td>1.787</td>
</tr>
<tr>
<td>4. SAWSDL-MX1</td>
<td>3.859</td>
<td>3.853</td>
</tr>
<tr>
<td>5. Nuwa-SAWSDL</td>
<td>9.009</td>
<td>8.986</td>
</tr>
<tr>
<td>6. iSeM 1.1</td>
<td>10.662</td>
<td>10.655</td>
</tr>
<tr>
<td>7. URBE</td>
<td>40.01</td>
<td>39.941</td>
</tr>
</tbody>
</table>

Vs. fastest variant

[AQRT; diff AP]: diff rank AQRT

[1.584s; - .018]: +3
Lesson Learned: Caching Strategies

SAWSDL matchmakers deal with required service ontologies quite differently

- Caching of complete ontologies *before* service registration
  - Ontologies are loaded and classified right after matchmaker plug-in initialization
  - Used by LOG4SWS.KOM, COV4SWS.KOM, SAWSDL-iMatcher

- Caching of self-contained (unfolded) concept definitions
  - Used by SAWSDL-MX1, iSeM 1.1

- Unknown strategy: URBE
Lesson Learned: Performance

- **Highest precision (AP):**

  - **Hybrid + Adaptive**
    - OWL-S: 0.92, OWL-S graded: 0.84, iSeM 1.1
    - SAWSDL: 0.84, SAWSDL graded: 0.8, iSeM 1.1

  - **Hybrid**
    - OWL-S: 0.88, OWL-S graded: 0.93, SeMa\(^2\) v2
    - SAWSDL: 0.84, SAWSDL graded: 0.90, LOG4SWS

  - **Logic-based**
    - OWL-S: 0.76, OWL-S graded: 0.87, EMMA
    - SAWSDL: -

  - **Non-logic-based**
    - OWL-S: 0.87, OWL-S graded: 0.92, iSeM-TSM1
    - SAWSDL: 0.82, SAWSDL graded: 0.88, COV4SWS, NUWA-SAWSWDL

- **Fastest response (AQRT):** 0.12s XSSD (OWL-S), 0.24s LOG4SWS (SAWSDL)

- **Best trade-off (AP\_B/AQRT; SAW, w\(_{1,2}\) = 0.5):** iSeM (.939, OWL-S), LOG4SWS (.973, SAWSDL)