Automatically Labeling the Inputs and Outputs of Web Services

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Find flight

Check weather forecast

Find hotels

Select hotel by price, features and reviews

Get distance to hotel

Reserve room for meeting

Reserve A/V equipment

Request a security card for visitor

Email agenda to attendees
**Example: Using Yahoo Distance Source**

**Request**

<table>
<thead>
<tr>
<th>addr</th>
<th>csz</th>
</tr>
</thead>
<tbody>
<tr>
<td>4676 Admiralty Way</td>
<td>90292</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>taddr</th>
<th>tcsz</th>
</tr>
</thead>
<tbody>
<tr>
<td>2547 Pier St</td>
<td>90404</td>
</tr>
</tbody>
</table>

**Response**

<table>
<thead>
<tr>
<th>dist</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4 miles</td>
</tr>
</tbody>
</table>

**Domain model**

- Place
  - Street
  - Zipcode
  - Latitude
  - Longitude
- Distance
- Weather
  - Temperature
  - Humidity

```
yahoo_dd(addr, csz, taddr, tcsz, dist) \rightarrow
distanceInMiles(Street, Zipcode, Street, Zipcode, Distance)
```
Information Integration

Information integration systems provide seamless access to heterogeneous information sources

- **Today...**
  - User must manually model an information source by specifying
    - Semantics of the input and output parameters
    - Functionality (operations) of the source

- **Tomorrow ...**
  - Automatically model new sources as they are discovered
  - Alternative solution: standards (Semantic Web, ...)
    - Slow to be adopted
    - Info providers may not agree on a common schema
Modeling Information Sources

- Research problem: Given a new source, automatically model it
  - Learn semantics of the input and output parameters (semantic labeling)
  - Learn operations it applies to the data (inducing functionality) (Carman & Knoblock, 2005)

- Focus on semantic labeling problem
  - Applied to Web services
    - Metadata readily available
    - Easy to extract data
  - Can be extended to RSS and Atom feeds, etc.
Web Services

Web services attempt to provide programmatic access to structured data

- Web service description (WSDL) file defines
  - Input and output parameters
  - Operations syntax

```
-<s:complexType name="ZipCodeCoordinates">
  <s:element name="LatDegrees" type="s:float"/>
  <s:element name="LonDegrees" type="s:float"/>
-<wsdl:message name="GetZipCodeCoordinatesSoapIn">
  <wsdl:part name="zip" type="s:string"/>
-<wsdl:message name="GetZipCodeCoordinatesSoapOut">
  <wsdl:part name="GetZipCodeCoordinatesResult" type="tns:ZipCodeCoordinates"/>
```

Service description is *syntactic* – client needs a priori understanding of the *semantics* to invoke the service
Our Approach to Semantic Labeling

We leverage existing knowledge to learn semantics of data used by Web services

- Background knowledge captured in a lightweight domain model
  - 80+ semantic types: Temperature, Zipcode, Flightnumber ...
  - Populated with examples of each type (from known sources)
  - Expandable

- Semantic labeling: mapping inputs/outputs to types in the domain model
  - Map input types based on metadata in WSDL file
  - Test by invoking Web service with examples of these types
  - Map output types based on content of data returned
Our Approach to Semantic Labeling

Leverage existing knowledge to learn semantics of data used by Web services

```
-<complexType=ZipCodeCoordinates>
  <element=LatDegrees type=s:float/>
  <element=LonDegrees type=s:float/>
</complexType>
```

Metadata based classifier

Invoke

Output data

Content-based classifier

Domain model

... Place
  Street
  Zipcode
  Latitude
  Longitude

... Distance

... Weather
  Temperature
  Humidity

80+ types with examples

80+ types with examples

USC Information Sciences Institute

AAAI-2006

Automatically Labeling Web Services

K. Lerman
Contributions

- **Metadata-based** classification
  - Logistic Regression classifier to label data used by Web services using metadata in the WSDL file
  - Automatically verify classification results by invoking the service

- **Content-based** classification
  - Label output data based on their content

- Automatically label live services
  - Weather and Geospatial domains
  - Combine metadata and content-based classification
Metadata-based Classification

- Observation 1
  Similar data types tend to be named with similar words, and/or belong to operations that have similar name
    - Treat as (ungrammatical) text classification problem
    - Approach taken by previous works

- Observation 2
  The classifier must be a soft classifier
    - Instance can belong to more than one class
    - Rank classification results
Naïve Bayes classifier
- Used to classify parameters used by Web services (Hess & Kushmerick, 2004)
  - Each input/output parameter represented by a term vector $t$
- Based on independence assumption
  - Terms are independent from each others given the class label $D$ (semantic type)
    $$P(D|t) \leftarrow \prod_i P(t_i|D)$$
  - Independence assumption unrealistic for Web services
    - e.g., “TempFahrenheit”: “Temp” and “Fahrenheit” often co-occur in the Temperature semantic type

Logistic regression avoids the independence assumption
- Estimates probabilities from the data
  $$P(D|t) = \logreg(wt)$$
Metadata-based Classification Evaluation

- **Data collection**
  - Data extracted from 313 WSDL files from Web service portals (bindingpoint and webservicex)

- **Data processing**
  - Names were extracted from operation, message, datatype and facet (predefined option)
  - Names tokenized into individual terms

- **10,000+ data types extracted**
  - Each one assigned to one of 80 classes in geospatial and weather domains (e.g. latitude, city, humidity).
  - Other classes treated as “Unknown” class
Evaluation Results

- Both Naïve bayes and Logistic regression were tested using 10-fold cross validation

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Top1</th>
<th>Top2</th>
<th>Top3</th>
<th>Top4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naïve Bayes</td>
<td>0.65</td>
<td>0.84</td>
<td>0.88</td>
<td>0.90</td>
</tr>
<tr>
<td>Logistic Regression</td>
<td>0.93</td>
<td>0.98</td>
<td>0.99</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Content-based Classification

✓ Idea: Learn a model of the content of data and use it to recognize new examples

Developed a domain-independent language to represent the structure of data

- Token-level
  - Specific tokens
  - General token types
    - based on syntactic categories of token’s characters

- Hierarchy of types
  - allows for multi-level generalization
Patterns for Describing Data

- Pattern is a sequence of tokens and general types
  - Phone numbers

<table>
<thead>
<tr>
<th>Examples</th>
<th>Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>310 448–8714</td>
<td>[(310) 448 – 4DIGIT]</td>
</tr>
<tr>
<td>310 448–8775</td>
<td>[(310) 448 – 4DIGIT]</td>
</tr>
<tr>
<td>212 555–1212</td>
<td>[(3DIGIT) 3DIGIT – 4DIGIT]</td>
</tr>
</tbody>
</table>

- Algorithm to learn patterns from examples
- Patterns for all semantic types in the domain model
Patterns for Semantic Labeling

- Use learned patterns to map new data to types in the domain model
  - Score how well patterns associated with a semantic type describe a set of examples
    - Heuristics include:
      - Number of matching patterns
      - How specific the matching patterns are
      - How many tokens of the example are left unmatched
  - Output four top-scoring types
Semantic Labeling Evaluation

Information domains and semantic types

- **Weather Services**
  - Temperature, SkyConditions, WindSpeed, WindDir, Visibility

- **Directory Services**
  - Name, Phone, Address

- **Electronics equipment purchasing**
  - ModelName, Manufacturer, DisplaySize, ImageBrightness, ...

- **UsedCars**
  - Model, Make, Year, BodyStyle, Engine, ...

- **Geospatial Services**
  - Address, City, State, Zipcode, Latitude, Longitude

- **Airline Flights**
  - Airline, flight number, flight status, gate, date, time
Evaluations Results

![Bar Chart](chart.png)

- **Directory 1**, **Directory 2**, **Directory 3**
- **Geospatial 1**, **Geospatial 2**, **Geospatial 3**
- **Cars 1**, **Cars 2**, **Cars 3**
Using all semantic types in classification

Restricting semantic types to domain of the source

Evaluations Results 2
Empirical Validation

- Automatically model the inputs and outputs used by Geospatial and Weather Web Services
  - Given the WSDL file of a new service
  - 8 services (13 operations)

- Results

<table>
<thead>
<tr>
<th>classifier</th>
<th>total</th>
<th>correct</th>
<th>accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>input parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>metadata-based</td>
<td>47</td>
<td>43</td>
<td>0.91</td>
</tr>
<tr>
<td><strong>output parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>metadata-based</td>
<td>213</td>
<td>145</td>
<td>0.68</td>
</tr>
<tr>
<td>content-based</td>
<td>213</td>
<td>107</td>
<td>0.50</td>
</tr>
<tr>
<td>combined</td>
<td>213</td>
<td>171</td>
<td>0.80</td>
</tr>
</tbody>
</table>
Conclusion

- Two algorithms for semantic labeling of data used by Web services
  - Metadata-based classification
    - Semantically label input and output parameters
  - Content-based classification
    - Semantically label output parameters

- Active testing
  - Invoke the service to verify classification results
  - Automatically verify classification results
Related Research

- Metadata-based classification of data types used by Web services and HTML forms (Hess & Kushmerick, 2003)
  - Naïve Bayes classifier
  - No invocation of services

- Woogle: Metadata-based clustering of data and operations used by Web services (Dong et al, 2004)
  - Groups similar types together: Zipcode, City, State
  - Cannot invoke services with this information

- Schema matching
  - Map instances of data from one database to another
    - Use metadata (schema names) and content features (word frequencies) (Li & Clifton 2000; Doan, Domingos & Halevy 2001)
    - No invocation – data is available
Future Directions

- Represent complex data types
  - Date
    - June 22, 2006
    - 06/22/06
    - Jun 22
  - But, we can correctly recognize Month, Day, Year

- Automate invocation and data collection

- Combine with ongoing work on modeling functionality of Web services

\[ \text{Svc}(\text{Zipcode}, \text{TempF}, \text{TempF}, \text{TempF}) \rightarrow \text{CurrentWeather}(\text{Zipcode}, \text{TempF}, \text{HiTemp}, \text{LoTemp}) \]