Automatically Labeling the Inputs and Outputs of Web Services

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Find hotels

Select hotel by price, features and reviews

Check weather forecast

Find flights

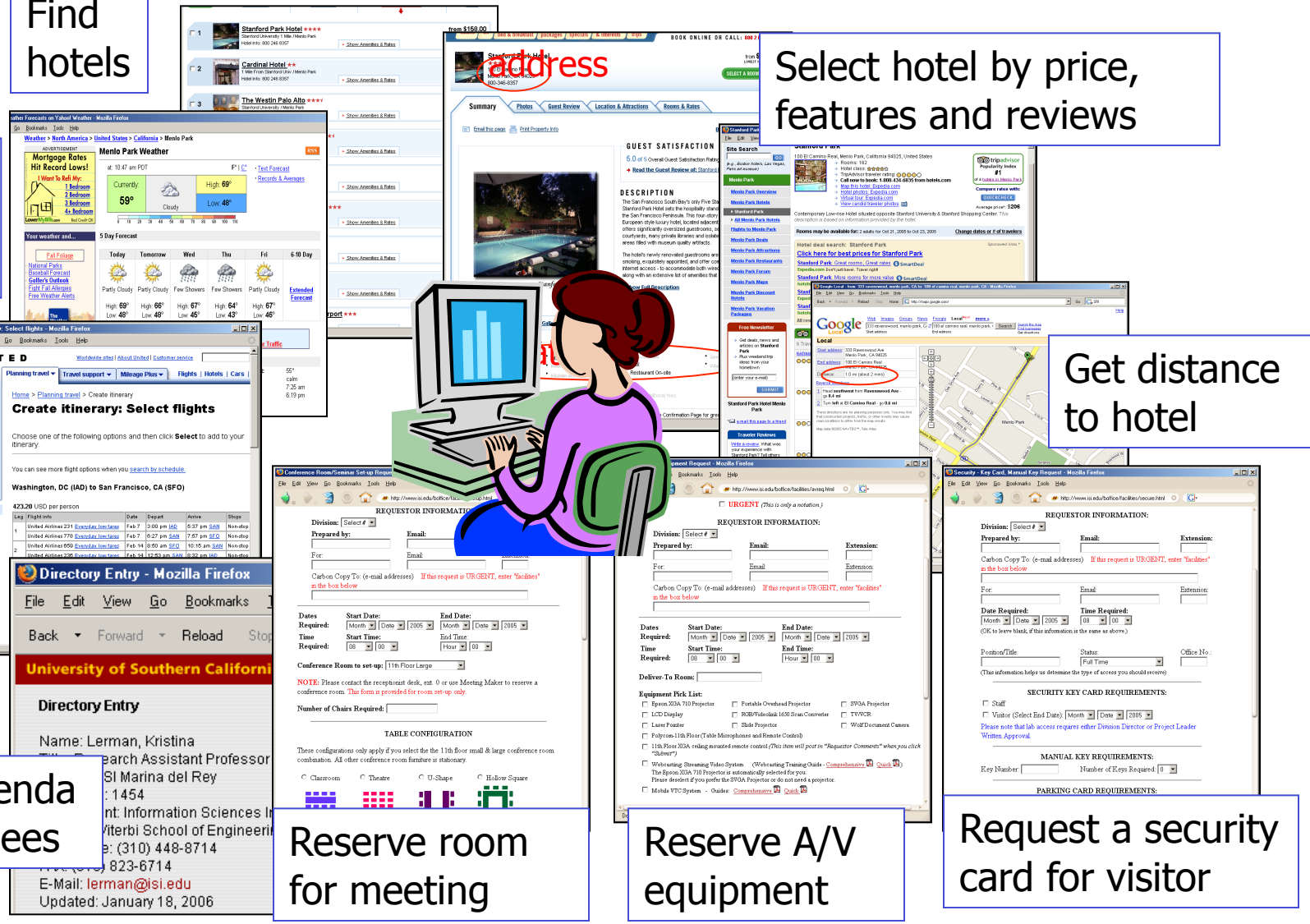
Get distance to hotel

Email agenda to attendees

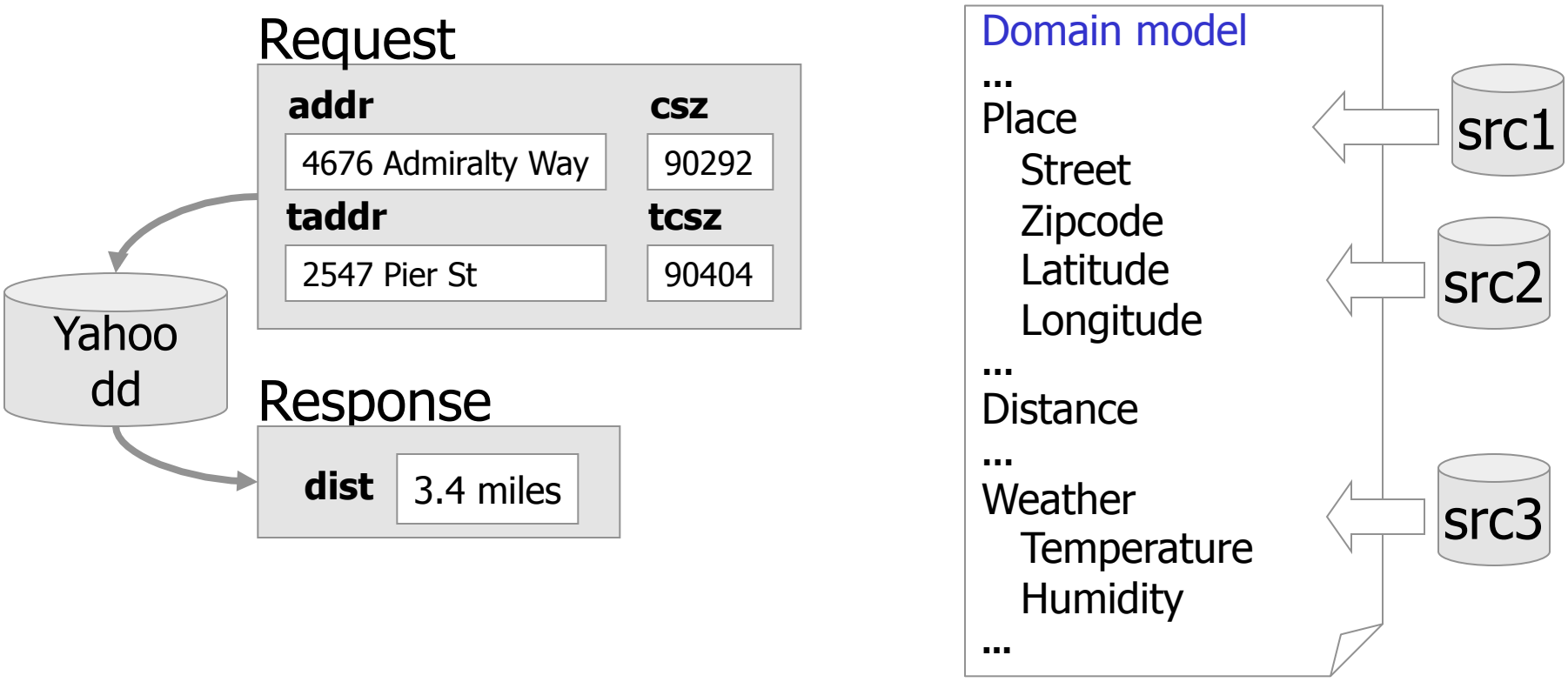
Reserve room for meeting

Reserve A/V equipment

Request a security card for visitor



Example: Using Yahoo Distance Source



yahoo_dd(addr,csz,taddr,tcsz,dist) →
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

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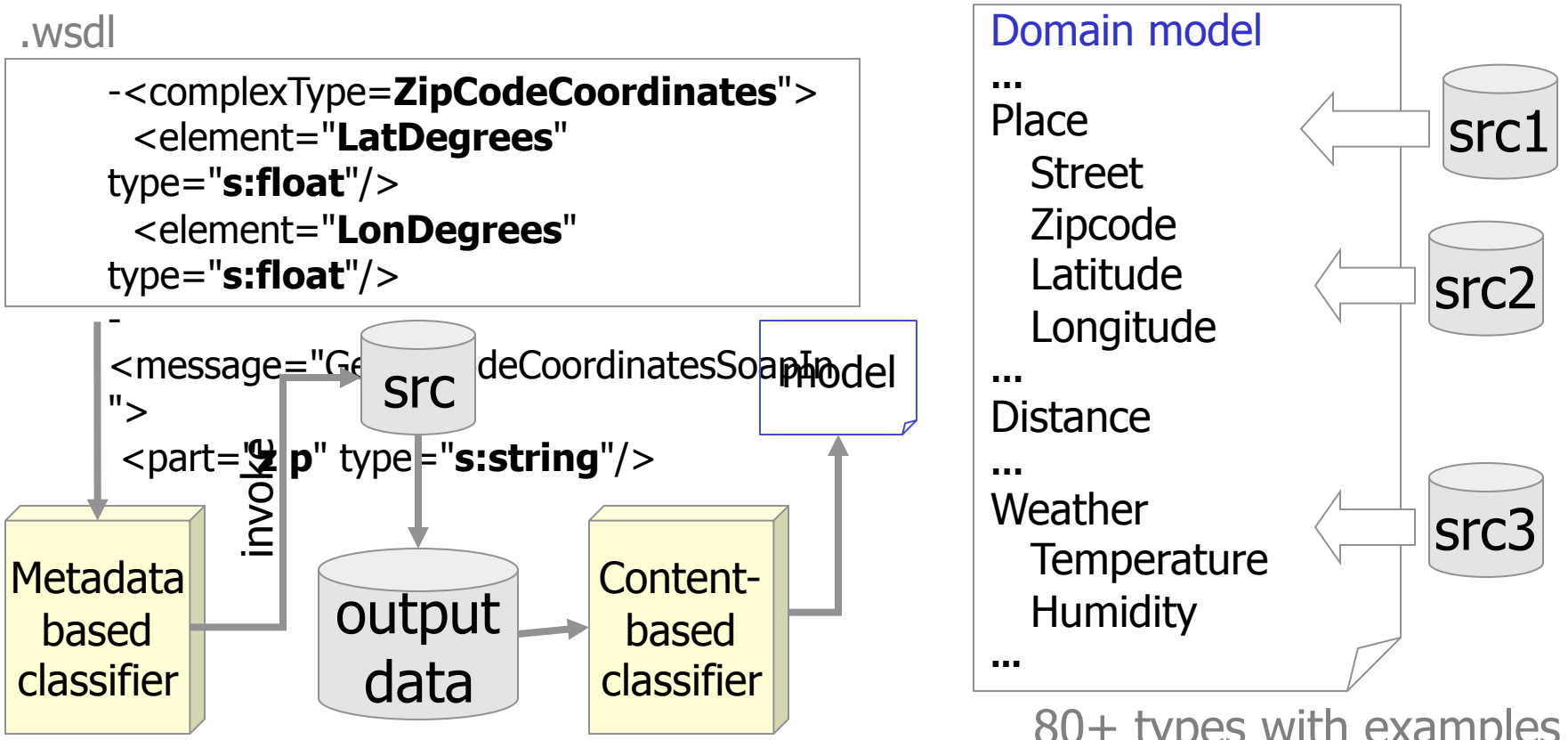


Contributions

- 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

Independence Assumption

- 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)

      $P(D|\boldsymbol{t}) \leftarrow \Pi_i \, P(t_i|D)$
    - 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

    $P(D|\boldsymbol{t}) = \text{logreg}(\boldsymbol{wt})$

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

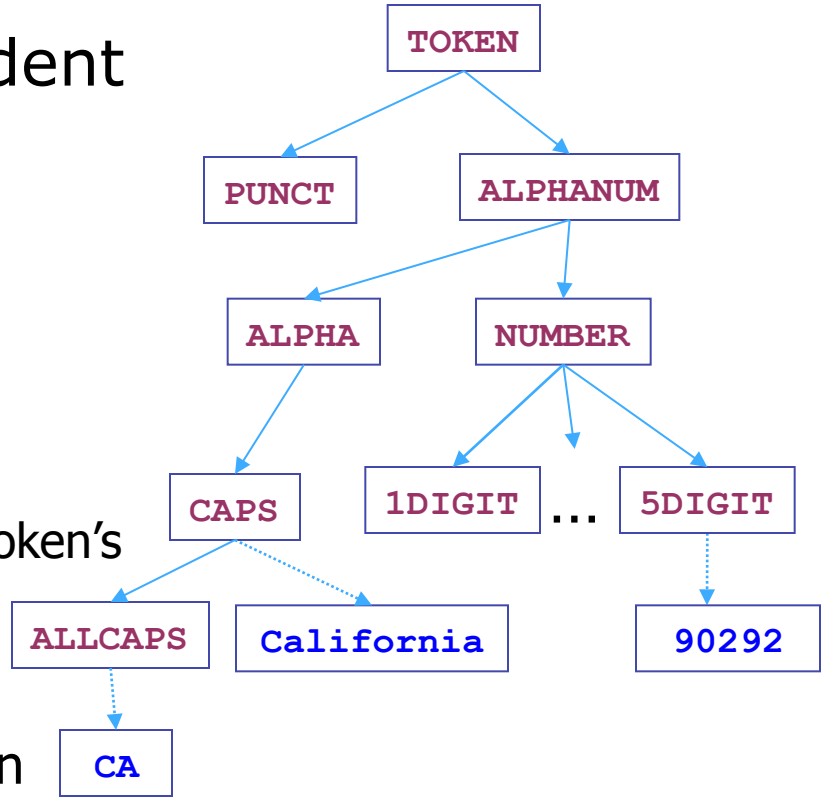
Classifier	Top1	Top2	Top3	Top4
Naïve Bayes	0.65	0.84	0.88	0.90
Logistic Regression	0.93	0.98	0.99	0.99

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

Examples	Patterns
310 448-8714	
310 448-8775	[(310) 448 – 4DIGIT]
212 555-1212	[(3DIGIT) 3DIGIT – 4DIGIT]

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

Patterns for Semantic Labeling

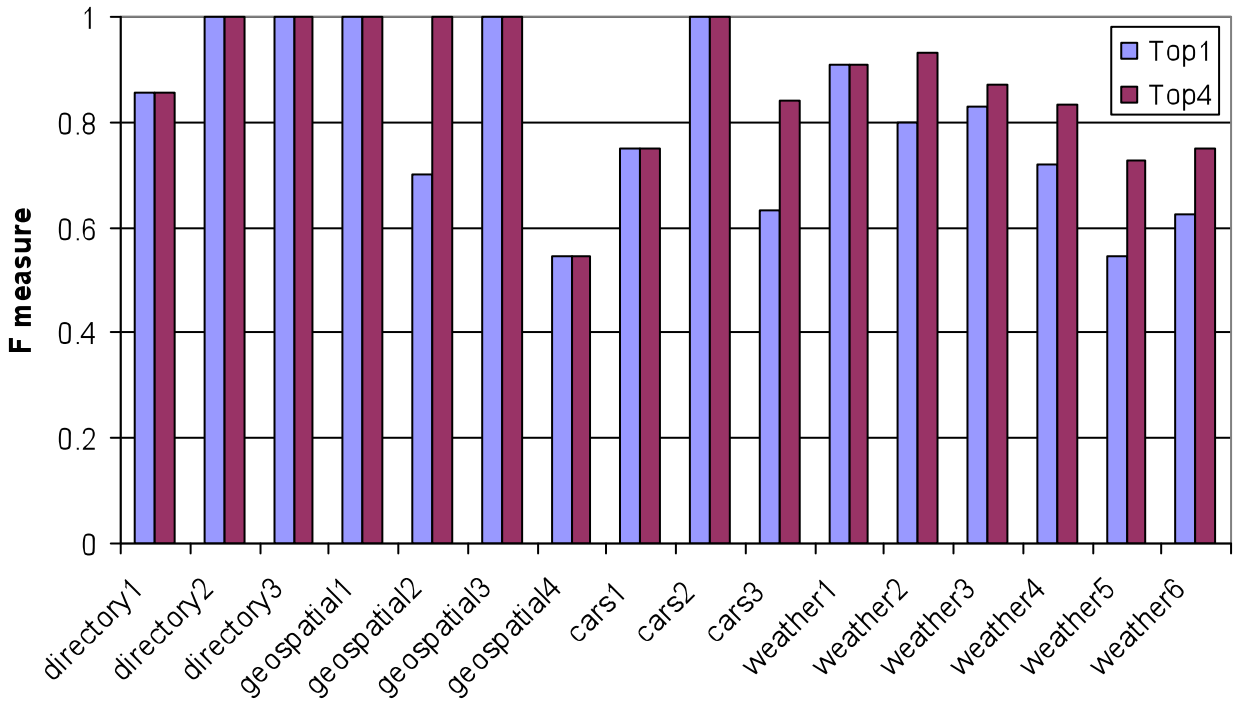
- Use learned patterns to map new data to types in the domain model
  - Score how well patterns associated with a semantic type describe a set of examples
    - Heuristics include:
      - Number of matching patterns
      - How specific the matching patterns are
      - How many tokens of the example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

Semantic Labeling Evaluation

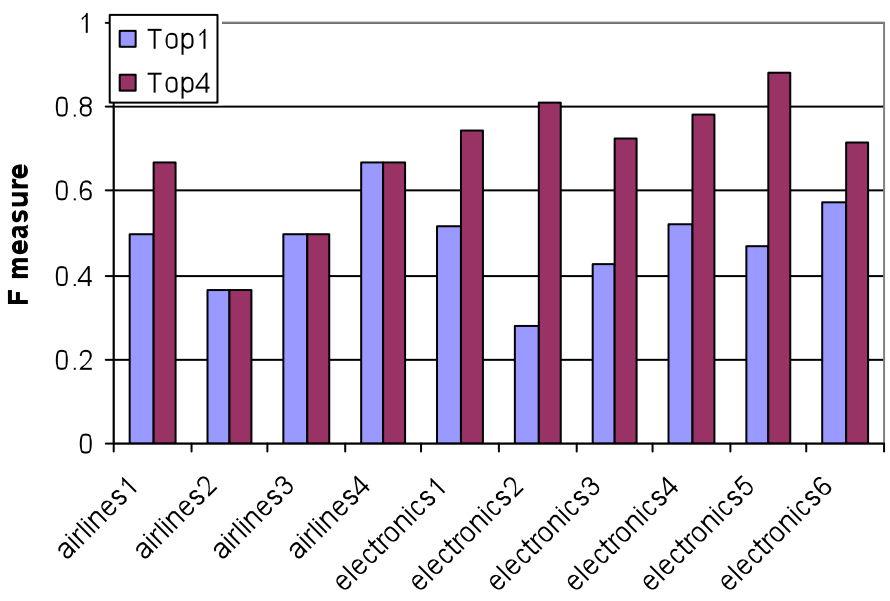
Information domains and semantic types

- 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

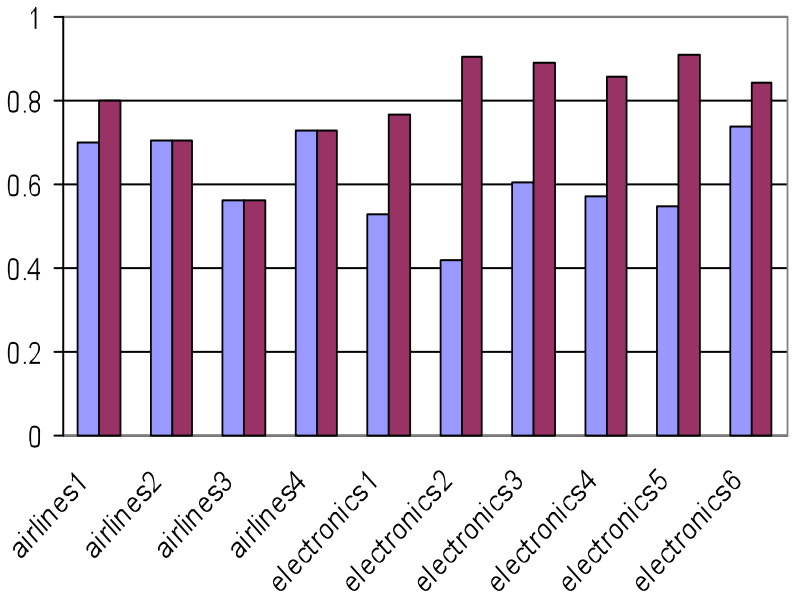
Evaluations Results



Evaluations Results 2



Using all semantic types in classification



Restricting semantic types to domain of the source

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

classifier	total	correct	accuracy
input parameters			
metadata-based	47	43	0.91
output parameters			
metadata-based	213	145	0.68
content-based	213	107	0.50
combined	213	171	0.80

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

  Svc(Zipcode, TempF, TempF, TempF) →
  CurrentWeather(Zipcode, TempF, HiTemp, LoTemp)