CONTEXTUAL ALIGNMENT OF ONTOLOGIES FOR SEMANTIC INTEROPERABILITY

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Overview

Aligned (Virtual) Combined Ontology

Ontology A1

Ontology A2

Ontology C

Aligned / Combined Airfare and Car Rental

Similar Ontologies Aligned via Context Modifiers

Airfare 1

Airfare 2

Car Rental

• Need to accommodate multiple ontology views simultaneous (A1 and A2)
• Need to integrate (combine) separately created ontologies (A1/A2 with C)
• Accomplished by contexts and conversion function networks
Use of Ontologies for COntext INterchange (COIN)

Concept: Length

Meters → Feet

Shared Ontologies

Conversion Libraries

Source Context

Select partlength x 3.35 From catalog
Where partno="12AY"

Receiver Context

Select partlength x 3.35 From catalog
Where partno="12AY"

Context Transformation

Source

Receiver

Part length

17

55.25
Ontologies & Interoperability: Assume Single Viewpoint

• For specific domains, ontologies provide a common language for integrating semantically heterogeneous sources.
• These ontologies are assumed to correspond to a single integrated view at a given time.
• Requires notoriously arduous process of agreeing on the meaning of ontological terms (e.g., what should “price” mean?)
• Introduces inflexibility for ontology development and evolution. Discourages and delays dev., adoption.
Example: Airfare Ontology

This ontology attaches a single meaning to:

Location (i.e. either as city names or Airport codes)
Date (i.e. European or American format)
Price (i.e. as nominal price or final price or …)
Money amount (i.e. in a specific currency)
…Or we unnecessarily clutter the Ontology

Is-a

Attribute

Fees

Flight

Money Amount

Location

Date

Price

Tax

ID

destination

origin

departure

return

price

tax

id

Location

Location as city names

Location as airport codes

European Date

American Date

One-way Nominal Price ($)

Roundtrip Nominal Price ($)
Single Ontology, Multiple Meanings

• Agree to disagree in a standard way
  – Abstracted ontology. Multiple meanings via contextualizing modifiers

• Allows an ontological term to acquire multiple meanings in different contexts

• Increased flexibility
  – Multiple integrated views
  – Reduced need for agreement on meanings

• Accomplished through the introduction of contexts
  – A generic context is a collection of modifiers
  – A modifier is a meta-attribute
    • support variability in representation
    • nuances in meaning
  – A specific context is a collection of modifier values
Airfare Ontology: Simplified Via Context Modifiers

Through the introduction of modifiers

- Currency
- L-format
- inclusion
- coverage

the above ontology allows variations in representation and nuances in meaning.
Multiple Meanings via Contexts

Context A1
- Currency → GBP
- L-Format → City
- Inclusion → Nominal+Tax+Fees
- Coverage → Round-trip

Context A2
- Currency → USD
- L-Format → Airport
- Inclusion → Nominal
- Coverage → One-way

Note: modifiers can have modifiers/contexts (e.g., currency code format)
Context Reconciliation via Conversion Function Network

Contexts

Context A1
Currency ➔ GBP
L-Format ➔ City
Inclusion ➔ Nominal+Tax+Fees
Coverage ➔ Round-trip

Context A2
Currency ➔ USD
L-Format ➔ Airport
Inclusion ➔ Nominal
Coverage ➔ One-way

Conversion Function Network

GBP ➔ currencyrates(GBP, USD, R, Date), mul(R,O,V)
USD ➔

City ➔ cityairport (C,A)

Nominal+Tax+Fees ➔ sub(X,F,V), sum(N,T,V)

Round Trip ➔ div(RT,2,O)

Nominal ➔

Coverage ➔

Inclusion ➔

L-Format ➔
AIRFARE SCENARIO

User A in Context A1
* Fares are expected to be bottom-line price (round trip, includes taxes and fees)
* Departure and Destination locations are expressed as city names
* Currency is GBP
* Today’s date: 05/01/04

Q1: SELECT Price FROM cheaptickets
WHERE DepartureDate = “06/01/04”
and ArrivalDate= “07/01/04” and
DepartureCity= “Boston”
and ArrivalCity= “Istanbul”;

Cheaptickets in Context A2
* All fares are for each way of travel and do not include fees and taxes.
* Currency is USD
* Service fee of $5 is charged
* Departure and Destination locations are expressed as three letter airport codes
* Lufthansa offers 10% discount if the airfare is bundled with National car rental

cheaptickets

<table>
<thead>
<tr>
<th>ID</th>
<th>Airline</th>
<th>Price</th>
<th>Tax</th>
<th>DepDate</th>
<th>ArrDate</th>
<th>DepCity</th>
<th>ArrCity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>British Airways</td>
<td>495</td>
<td>75</td>
<td>06/01/04</td>
<td>08/01/04</td>
<td>BOS</td>
<td>IST</td>
</tr>
<tr>
<td>2</td>
<td>Lufthansa</td>
<td>510</td>
<td>77</td>
<td>06/01/04</td>
<td>08/01/04</td>
<td>BOS</td>
<td>IST</td>
</tr>
</tbody>
</table>

currencyrates

<table>
<thead>
<tr>
<th>FromCur</th>
<th>ToCur</th>
<th>eRate</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBP</td>
<td>USD</td>
<td>1.75</td>
<td>05/01/04</td>
</tr>
<tr>
<td>EUR</td>
<td>USD</td>
<td>1.25</td>
<td>05/01/04</td>
</tr>
</tbody>
</table>

cityairport

<table>
<thead>
<tr>
<th>City</th>
<th>Airport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston</td>
<td>BOS</td>
</tr>
<tr>
<td>Istanbul</td>
<td>IST</td>
</tr>
</tbody>
</table>

Currencyrates and cityairport are supplemental data sources, used by conversion function network.
MEDIATED QUERY (MQ1): SELECT Airline, (2* (Price+Tax) + 5) * eRate FROM cheaptickets, currencyrates, (select Airport from cityairport where city= “Boston”) cityairport1, (select Airport from cityairport where city= “Istanbul”) cityairport2 WHERE DepDate = “06/01/04” and ArrDate= ”07/01/04” and DepCity= cityairport1.Airport and ArrCity= cityairport2.Airport and fromCur= “USD” and toCur= “GBP” and Date= “05/10/04”;

Results:

<table>
<thead>
<tr>
<th>Airline</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Airways</td>
<td>654</td>
</tr>
<tr>
<td>Lufthansa</td>
<td>674</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID</th>
<th>Airline</th>
<th>Price</th>
<th>Tax</th>
<th>DepDate</th>
<th>ArrDate</th>
<th>DepCity</th>
<th>ArrCity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>British Airways</td>
<td>495</td>
<td>75</td>
<td>06/01/04</td>
<td>08/01/04</td>
<td>BOS</td>
<td>IST</td>
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</tbody>
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<th>eRate</th>
<th>Date</th>
</tr>
</thead>
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<tr>
<td>GBP</td>
<td>USD</td>
<td>1.75</td>
<td>05/01/04</td>
</tr>
<tr>
<td>EUR</td>
<td>USD</td>
<td>1.25</td>
<td>05/01/04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>City</th>
<th>Airport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston</td>
<td>BOS</td>
</tr>
<tr>
<td>Istanbul</td>
<td>IST</td>
</tr>
</tbody>
</table>
2nd Ontology: European Car Rental

Note: Shared understanding (assumption) that currency is Euros and European style dates, thus no modifiers included in this ontology.
CAR RENTAL SCENARIO

User C in Context C1
* Rentals are expected to be bottom-line price (includes taxes, and fees)
* Rates are for the rental duration

Cheaprentals in Context C2
* Rentals do not include fees and taxes.
* Rates are daily
* National offers 10% discount if the car rental is bundled with a Lufthansa airfare
* Airport concession recovery fee %10
* Sales tax is 5%

Q2: SELECT Price FROM cheaprentals
WHERE Class= “Economy” and
PickDate = “02/06/04” and
DropDate= “01/07/04” and
Pickup= “IST” and DropOff= “IST”;

cheaprentals

<table>
<thead>
<tr>
<th>ID</th>
<th>Company</th>
<th>Pickup</th>
<th>DropOff</th>
<th>PickDate</th>
<th>DropDate</th>
<th>Price</th>
<th>Class</th>
<th>RatePeriod</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hertz</td>
<td>IST</td>
<td>IST</td>
<td>02/06/04</td>
<td>01/07/04</td>
<td>23.99</td>
<td>Economy</td>
<td>Daily</td>
</tr>
<tr>
<td>2</td>
<td>National</td>
<td>IST</td>
<td>IST</td>
<td>02/06/04</td>
<td>01/07/04</td>
<td>27.99</td>
<td>Economy</td>
<td>Daily</td>
</tr>
</tbody>
</table>

Note: Shared understanding in C1 and C2 that currency is Euros and European style dates.
MEDIATED QUERY (MQ2):
SELECT Company, Price * 34.65
FROM cheaprentals, (select Airport from cityairport where city= "Istanbul") cityairport
WHERE Class= "Economy" and PickDate = "02/06/04" and DropDate= "01/07/04" and Pickup= cityairport.Airport and DropOff= cityairport.Airport;

Note: 34.65 = 30 * 1.1 * 1.05, Includes total rental days, concession fee, and sales tax

Q2: SELECT Price
FROM cheaprentals
WHERE Class= "Economy" and PickDate = "02/06/04" and DropDate= "01/07/04" and Pickup= "IST" and DropOff= "IST";

Results:

<table>
<thead>
<tr>
<th>Company</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hertz</td>
<td>831</td>
</tr>
<tr>
<td>National</td>
<td>998</td>
</tr>
</tbody>
</table>

cheaprentals

<table>
<thead>
<tr>
<th>ID</th>
<th>Company</th>
<th>Pickup</th>
<th>DropOff</th>
<th>PickDate</th>
<th>DropDate</th>
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<td>IST</td>
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<td>01/07/04</td>
<td>27.99</td>
<td>Economy</td>
<td>Daily</td>
</tr>
</tbody>
</table>
User Merged Context M1
* Both Rentals and Fares are expected to be bottom-line & bundle price
* Date is expressed in American style
* Both Rental and flight locations are expressed as city names
* Currency is Euros

Q3: SELECT Airline, Company, t.Price + r.Price as total
FROM cheaptickets t, cheaprentals r
WHERE DepDate = "06/01/04"
and ArrDate = "07/01/04"
and DepCity = "Boston"
and ArrCity = "Istanbul";
Pickup = "Istanbul" and Dropoff = "Istanbul" and PickDate = "06/02/04" and DropDate = "07/01/04";

<table>
<thead>
<tr>
<th>ID</th>
<th>Airline</th>
<th>Price</th>
<th>Tax</th>
<th>DepDate</th>
<th>ArrDate</th>
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<table>
<thead>
<tr>
<th>ID</th>
<th>Company</th>
<th>Pickup</th>
<th>DropOff</th>
<th>PickDate</th>
<th>DropDate</th>
<th>Price</th>
<th>Class</th>
<th>RatePeriod</th>
</tr>
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<tbody>
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<td>1</td>
<td>Herts</td>
<td>IST</td>
<td>IST</td>
<td>02/06/04</td>
<td>01/07/04</td>
<td>23.99</td>
<td>Economy</td>
<td>Daily</td>
</tr>
<tr>
<td>2</td>
<td>National</td>
<td>IST</td>
<td>IST</td>
<td>02/06/04</td>
<td>01/07/04</td>
<td>27.99</td>
<td>Economy</td>
<td>Daily</td>
</tr>
</tbody>
</table>
Merging Overview (abbreviated)

Hybrid of:

• **Ontology Merging**
  – Produce new (but virtual) ontology
  – Inherits from base ontologies
    • Car rental gains city name <---> airport code capabilities from Air fare ontology

• **Alignment Approaches**
  – Use articulation axioms to align ontologies
  – New terms, relationships, and modifiers can be added
    • Multiple date formats now exist, so need date format modifier
    • “Bundled” price concept added

Conversion Network also extended

• To handle “bundling”, date format, currency format conversions
**MEDIATED QUERY**

```sql
SELECT "Lufthansa", "National", ((2 * (t.Price + Tax )+5) * eRate + r.Price * 34.65) * 0.9 as total
FROM cheaptickets t, currencyrates, cheaprentals r,
     (select Airport from cityairport where city= "Boston") cityairport1,
     (select Airport from cityairport where city= "Istanbul") cityairport2
WHERE DepDate = "06/01/04" and ArrDate="07/01/04" and   DepCity= cityairport1.Airport and
  ArrCity= cityairport2.Airport and fromCur= "USD" and toCur= "EUR" and Date= "05/10/04" and
  Airline="Lufthansa" and Company="National" and Class= "Economy" and PickDate = "02/06/04" and
  DropDate= "01/07/04" and Pickup= cityairport2.Airport and DropOff= cityairport2.Airport
UNION
SELECT Airline, Company, ((2 * (t.Price + Tax )+5) * eRate + r.Price * 34.65) as total
FROM cheaptickets t, currencyrates, cheaprentals r, (select Airport from cityairport where city= "Boston")
     cityairport1, (select Airport from cityairport where city= "Istanbul") cityairport2
WHERE DepDate = "06/01/04" and ArrDate="07/01/04" and   DepCity= cityairport1.Airport and
  ArrCity= cityairport2.Airport and fromCur= "USD" and toCur= "EUR" and Date= "05/10/04" and
  (Airline<>"Lufthansa" or Company<>"National") and Class= "Economy" and PickDate = "02/06/04" and
  DropDate= "01/07/04" and Pickup= cityairport2.Airport and DropOff=cityairport2.Airport
```

**Results:**

<table>
<thead>
<tr>
<th>Airline</th>
<th>Company</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Airways</td>
<td>Hertz</td>
<td>1747</td>
</tr>
<tr>
<td>British Airways</td>
<td>National</td>
<td>1913</td>
</tr>
<tr>
<td>Lufthansa</td>
<td>Hertz</td>
<td>1775</td>
</tr>
<tr>
<td>Lufthansa</td>
<td>National</td>
<td>1747</td>
</tr>
</tbody>
</table>
Conclusions

• A single ontology can accommodate multiple views
  – Through use of context modifiers and
  – Conversion function network
• “Virtually” merged application
  – Creates illusion of a single system
  – Can go across sources & across domains
  – Cross-fertilization of contexts and conversion functions
• Ontology interoperability to support multiple integrated views across domains