CONTEXTUAL ALIGNMENT OF ONTOLOGIES FOR SEMANTIC INTEROPERABILITY

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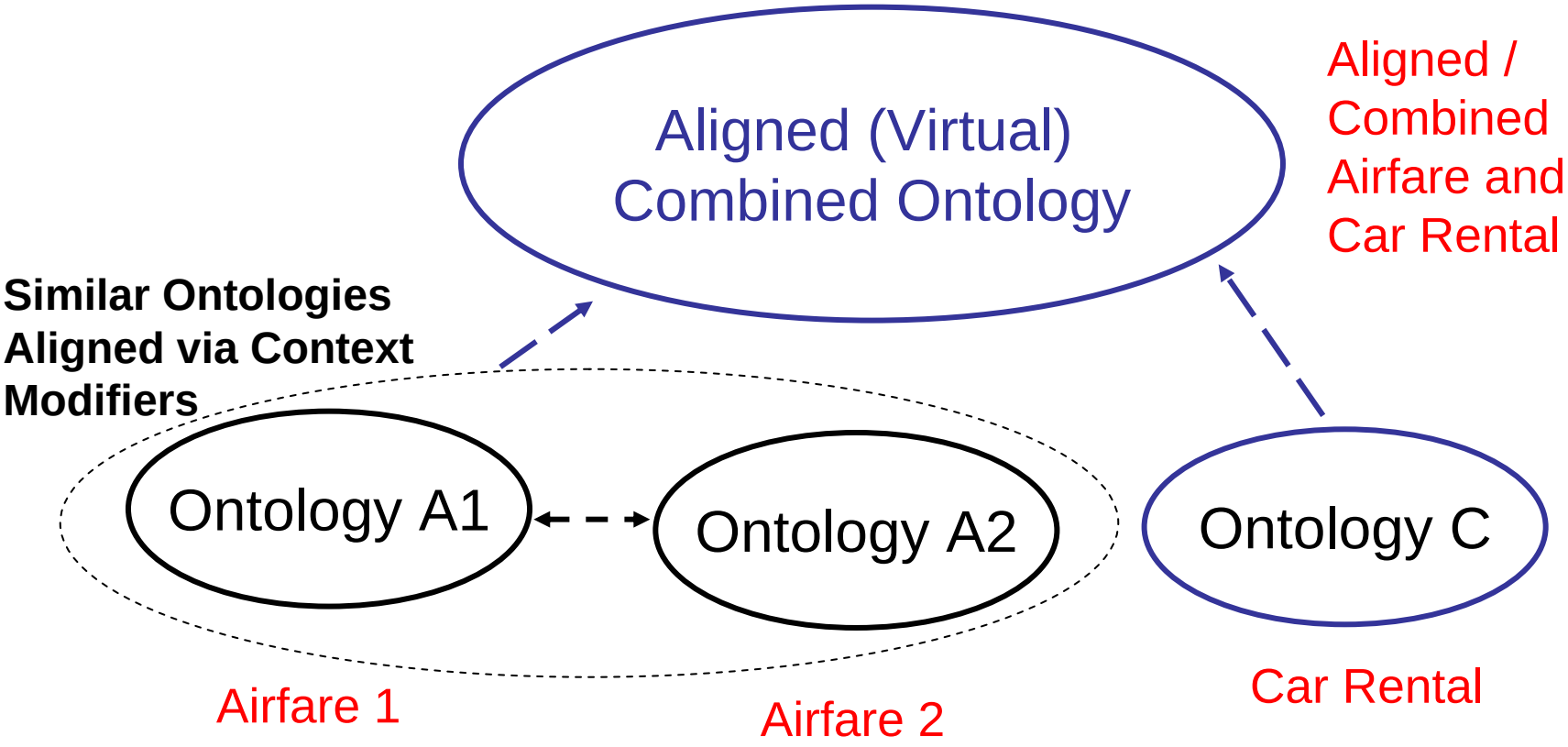
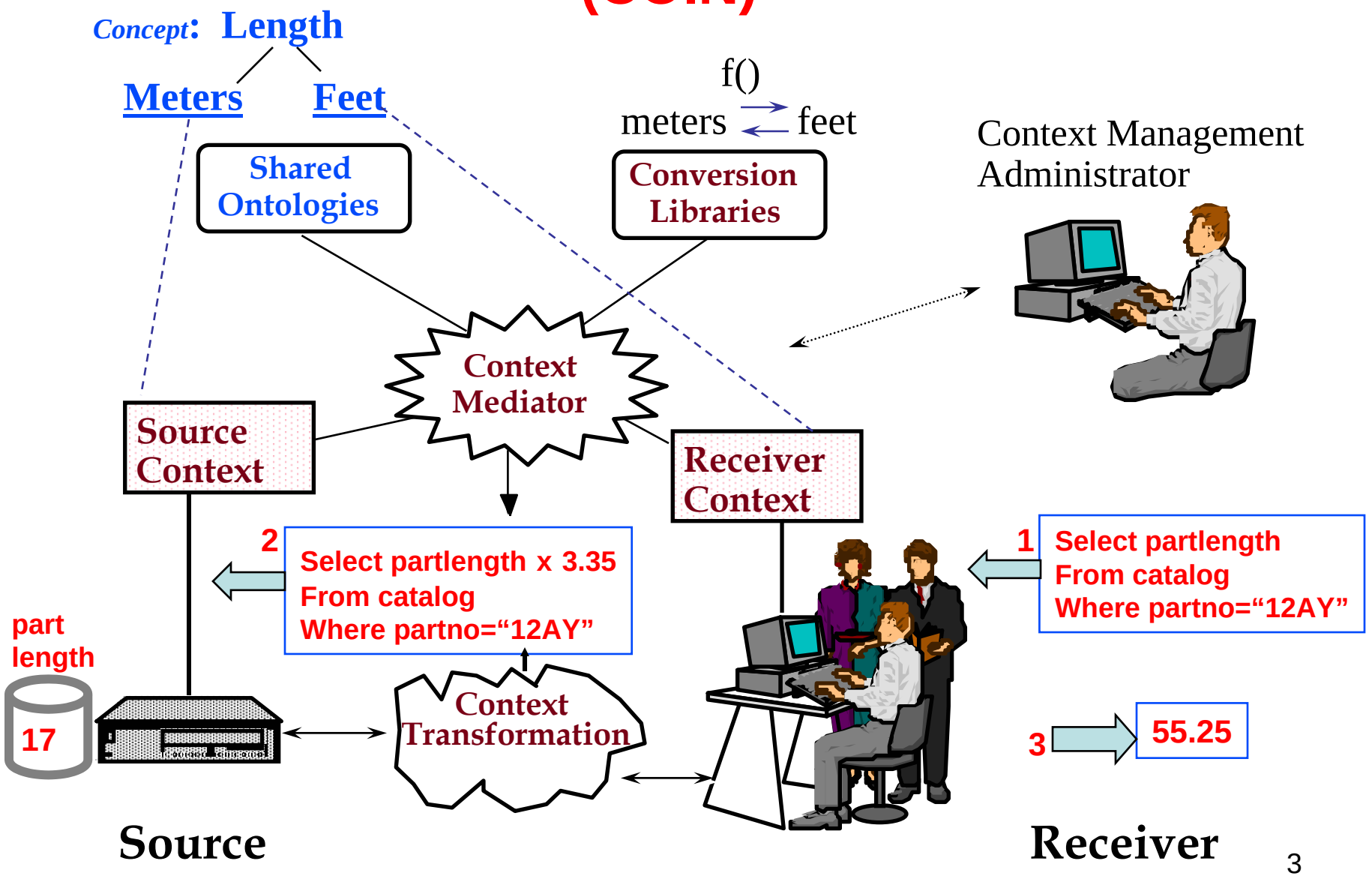
Workshop on Information Technologies And Systems (WITS'04)
George Mason University (Arlington campus)
Washington, DC, USA
December 11-12, 2004

Overview



- **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***

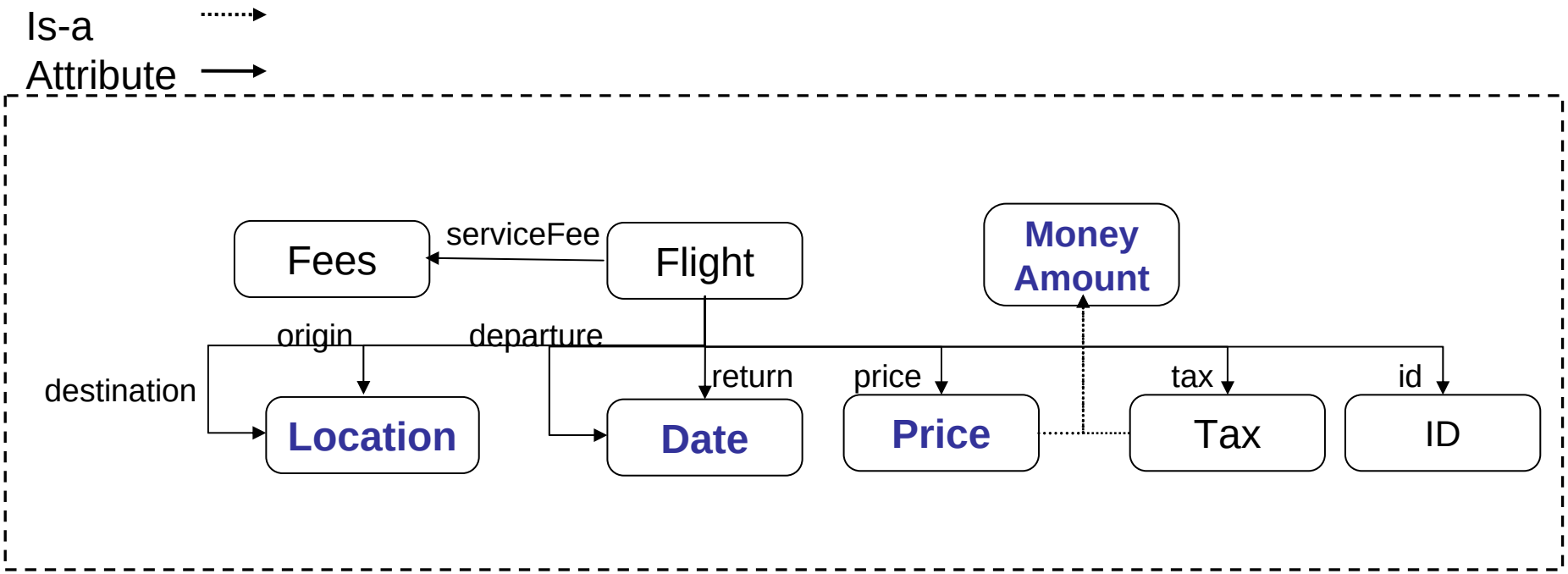
Use of Ontologies for COntext INterchange (COIN)



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.

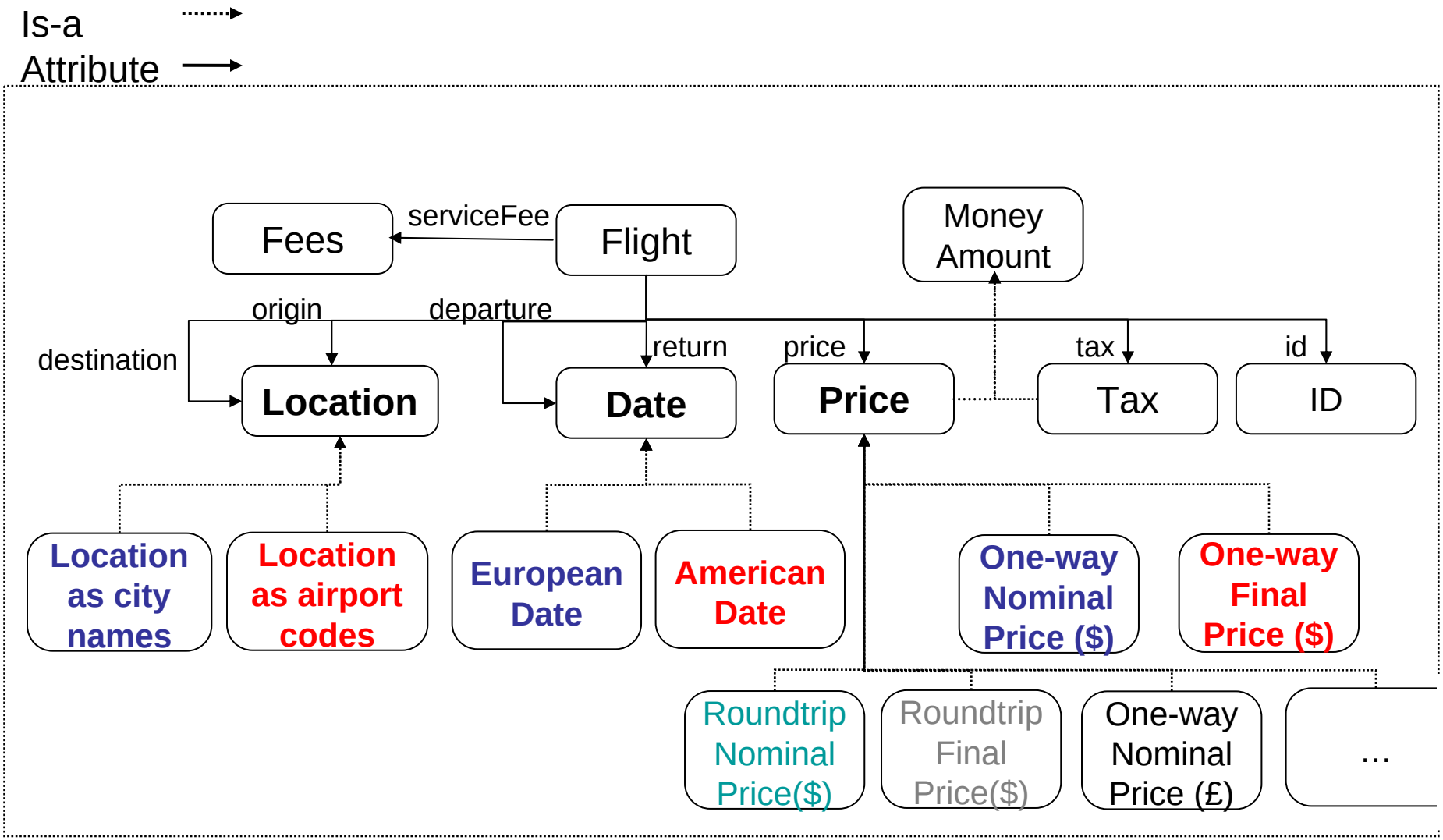
Example: Airfare Ontology



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)

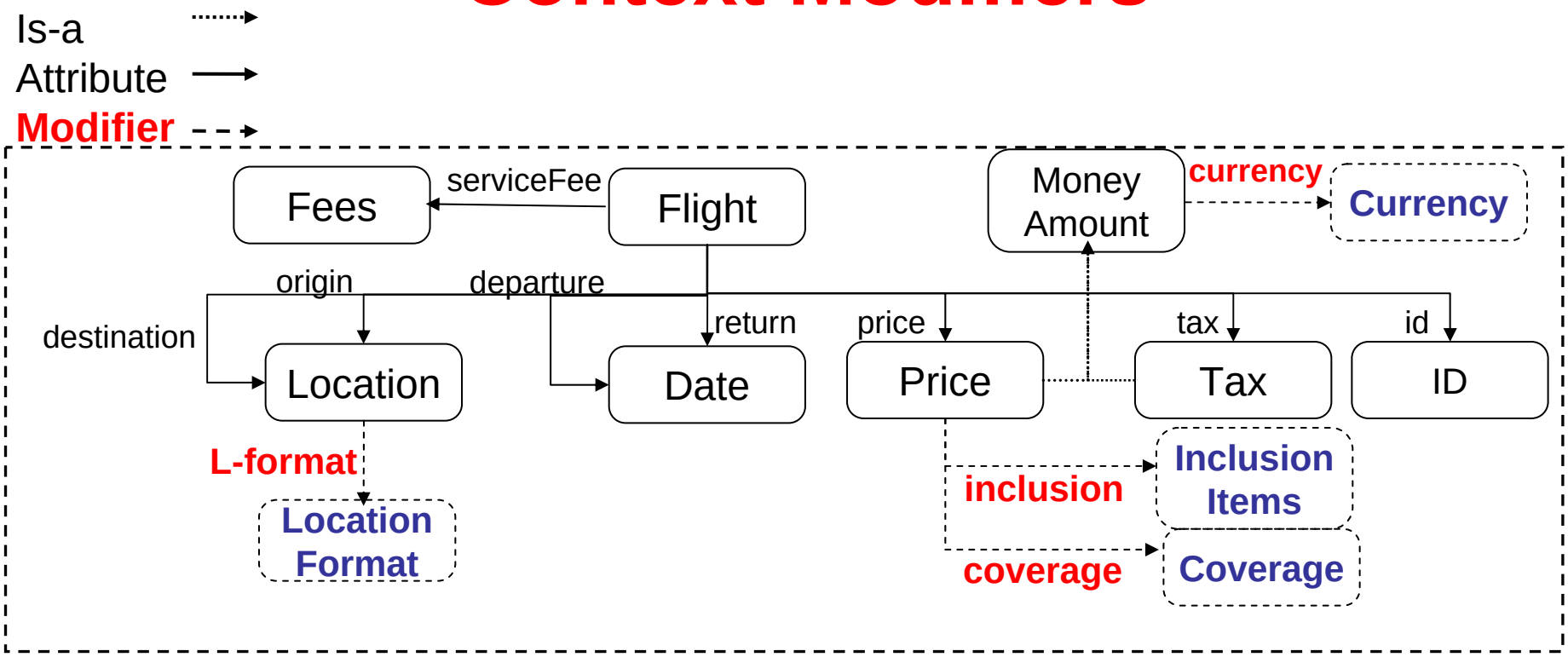
…Or we unnecessarily clutter the Ontology



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

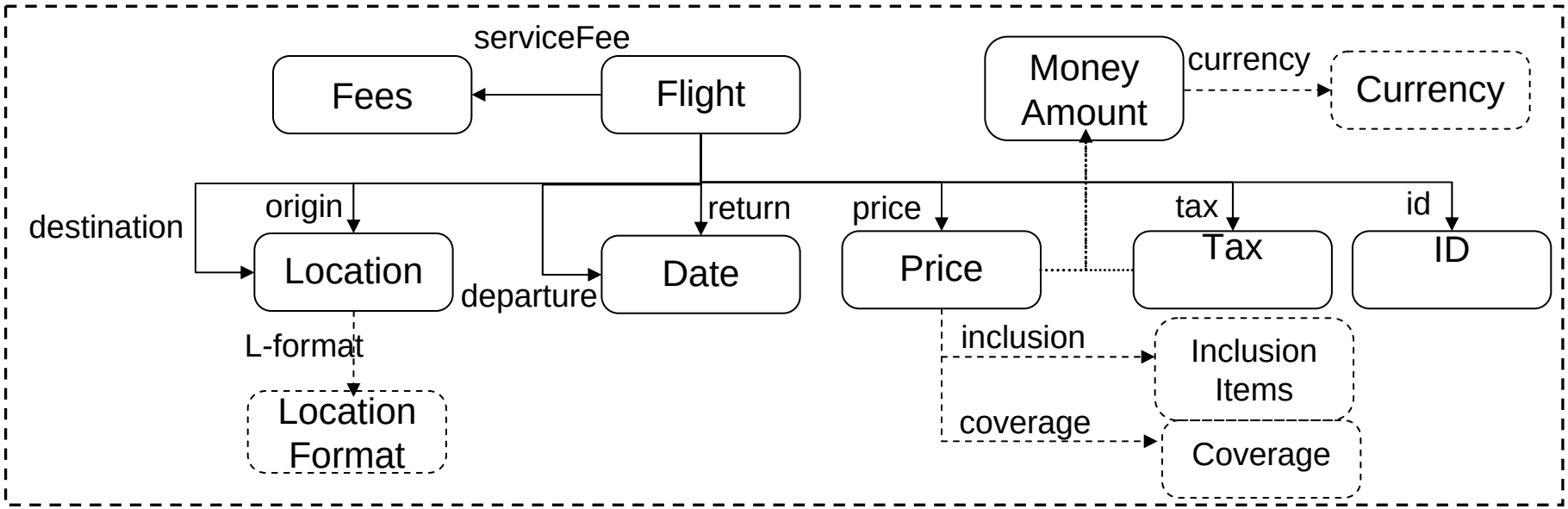


Through the introduction of modifiers

Currency, L-format, inclusion and coverage,

the above ontology allows variations in representation and nuances in meaning.

Multiple Meanings via Contexts



Contexts

Context A1

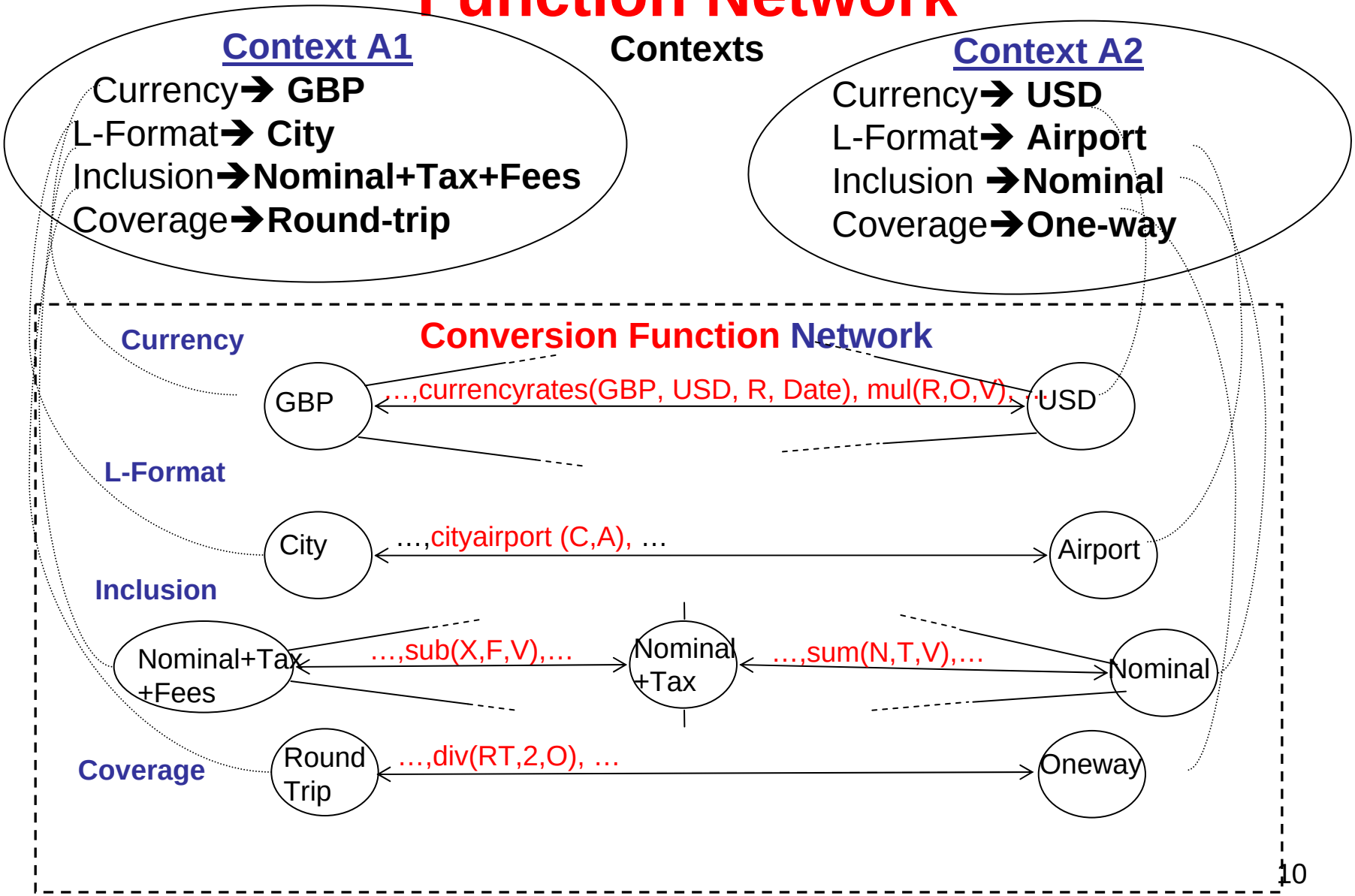
Currency➔ **GBP**
L-Format➔ **City**
Inclusion➔ **Nominal+Tax+Fees**
Coverage➔**Round-trip**

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

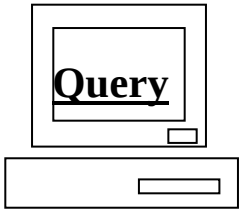


AIRFARE SCENARIO

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

ID	Airline	Price	Tax	DepDate	ArrDate	DepCity	ArrCity
1	British Airways	495	75	06/01/04	08/01/04	BOS	IST
2	Lufthansa	510	77	06/01/04	08/01/04	BOS	IST

currencyrates

FromCur	ToCur	eRate	Date
GBP	USD	1.75	05/01/04
EUR	USD	1.25	05/01/04

cityairport

City	Airport
Boston	BOS
Istanbul	IST

Currencyrates and cityairport are supplemental data sources, used by conversion function network

AIRFARE RESULTS

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

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:

Airline	Price
British Airways	654
Lufthansa	674

cheaptickets

ID	Airline	Price	Tax	DepDate	ArrDate	DepCity	ArrCity
1	British Airways	495	75	06/01/04	08/01/04	BOS	IST
2	Lufthansa	510	77	06/01/04	08/01/04	BOS	IST

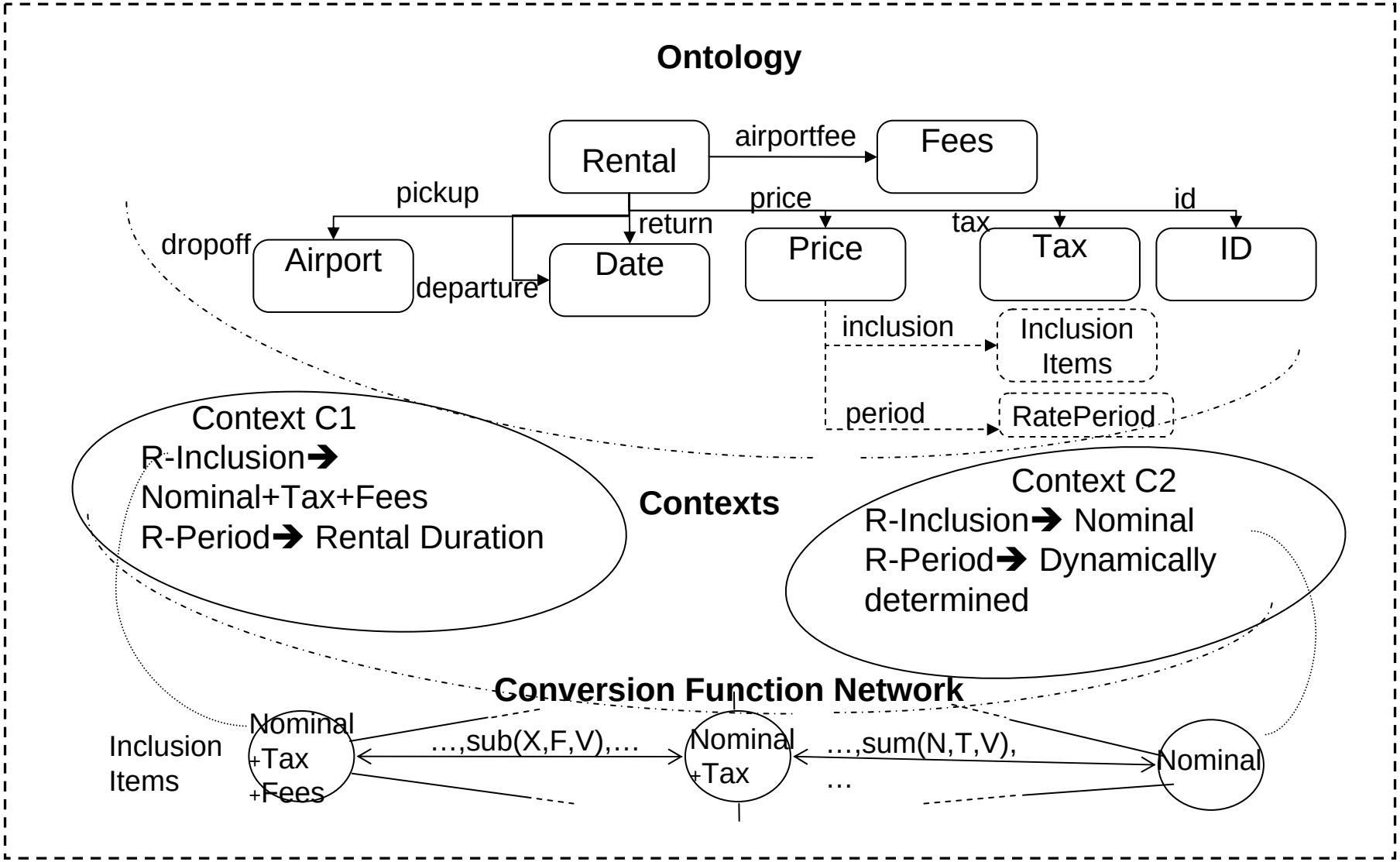
currencyrates

FromCur	ToCur	eRate	Date
GBP	USD	1.75	05/01/04
EUR	USD	1.25	05/01/04

cityairport

City	Airport
Boston	BOS
Istanbul	IST

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

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 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%

cheaprentals

ID	Company	Pickup	DropOff	PickDate	DropDate	Price	Class	RatePeriod
1	Hertz	IST	IST	02/06/04	01/07/04	23.99	Economy	Daily
2	National	IST	IST	02/06/04	01/07/04	27.99	Economy	Daily

Note: Shared understanding in C1 and C2 that currency is Euros and European style dates.

CAR RENTAL RESULTS

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

MEDIATED QUERY (MQ2):

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

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;

Results:

Company	Price
Hertz	831
National	998

cheaprentals

ID	Company	Pickup	DropOff	PickDate	DropDate	Price	Class	RatePeriod
1	Hertz	IST	IST	02/06/04	01/07/04	23.99	Economy	Daily
2	National	IST	IST	02/06/04	01/07/04	27.99	Economy	Daily

AIRFARE & CAR RENTAL APPLICATIONS COMBINED

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**

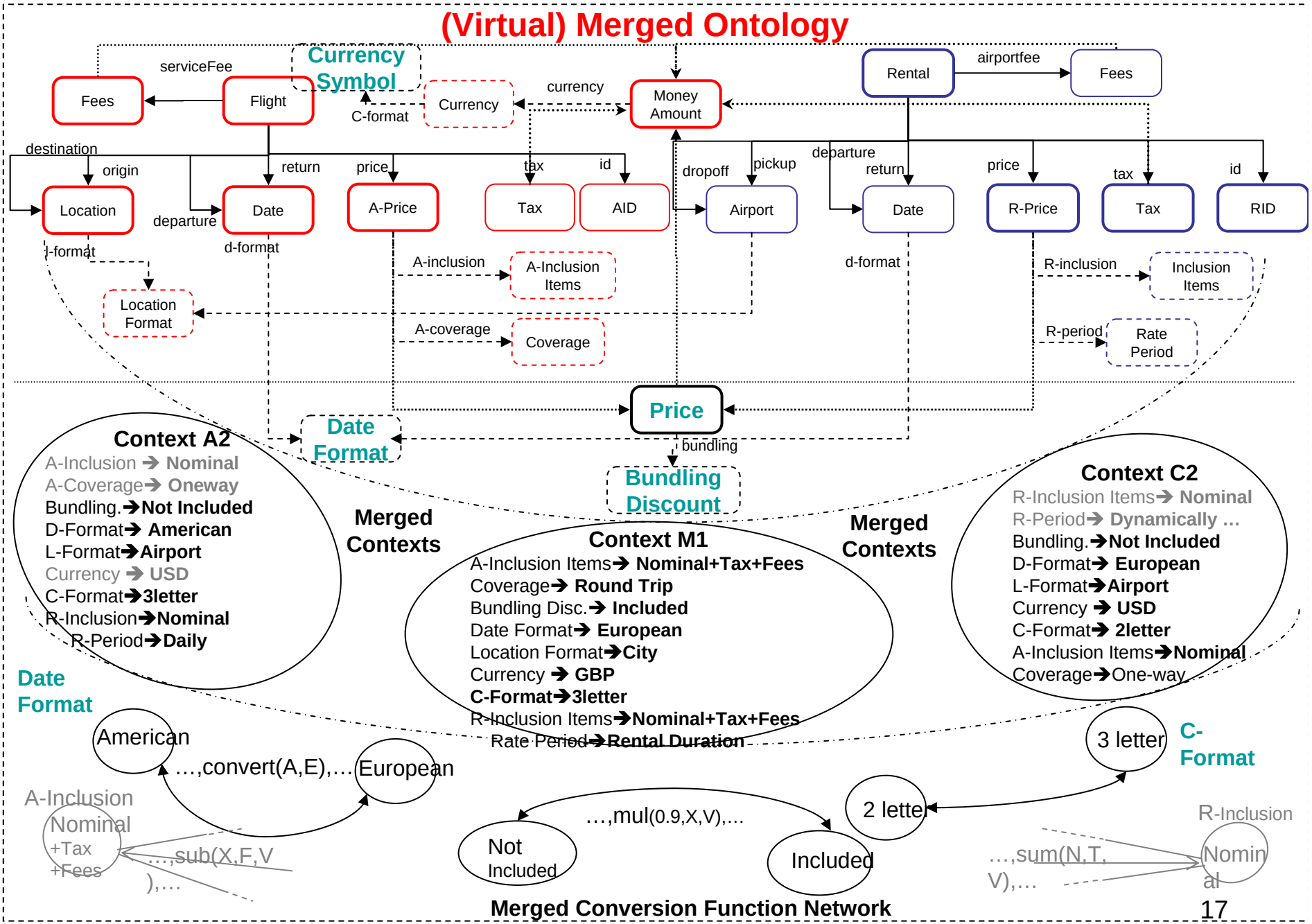
```
Q3: SELECT Airline, Company, t.Price + r.Price
as total
FROM cheaptickets t, cheaprentals r
WHERE DepDate = “06/01/04”
and ArrDate=  “07/01/04”
and  DepCity= “Boston”
and ArrCity= “Istanbul”;
Pickup="Istanbul" and Dropoff="Istanbul" and
PickDate="06/02/04" and DropDate="07/01/04";
```

cheaptickets

ID	Airline	Price	Tax	DepDate	ArrDate	DepCity	ArrCity
1	British Airways	495	75	06/01/04	08/01/04	BOS	IST
2	Lufthansa	510	77	06/01/04	08/01/04	BOS	IST

cheaprentals

ID	Company	Pickup	DropOff	PickDate	DropDate	Price	Class	RatePeriod
1	Herts	IST	IST	02/06/04	01/07/04	23.99	Economy	Daily
2	National	IST	IST	02/06/04	01/07/04	27.99	Economy	Daily


(Virtual) Merged Ontology
Currency Symbol
serviceFee
Fees
Flight
C-format
Currency
currency
Money Amount
Rental
airportfee
Fees
destination
origin
return
price
tax
id
dropoff
pickup
departure
return
price
tax
id
Location
departure
Date
A-Price
Tax
AID
Airport
Date
R-Price
Tax
RID
l-format
d-format
A-inclusion
A-Inclusion Items
d-format
R-inclusion
Inclusion Items
Location Format
A-coverage
Coverage
R-period
Rate Period
Price
Date Format
bundling
Bundling Discount
Context A2
A-Inclusion ➔ Nominal
A-Coverage➔ Oneway
Bundling.➔Not Included
D-Format➔ American
L-Format➔Airport
Currency ➔ USD
C-Format➔3letter
R-Inclusion➔Nominal
R-Period➔Daily
Merged Contexts
Context M1
A-Inclusion Items➔ Nominal+Tax+Fees
Coverage➔ Round Trip
Bundling Disc.➔ Included
Date Format➔ European
Location Format➔City
Currency ➔ GBP
C-Format➔3letter
R-Inclusion Items➔Nominal+Tax+Fees
Rate Period➔Rental Duration
Merged Contexts
Context C2
R-Inclusion Items➔ Nominal
R-Period➔ Dynamically …
Bundling.➔Not Included
D-Format➔ European
L-Format➔Airport
Currency ➔ USD
C-Format➔ 2letter
A-Inclusion Items➔Nominal
Coverage➔One-way
Date Format
American
…,convert(A,E),…
European
3 letter
C-Format
A-Inclusion
Nominal
+Tax
+Fees
…,sub(X,F,V),…
…,mul(0.9,X,V),…
2 letter
Not Included
Included
R-Inclusion
…,sum(N,T,V),…
Nominal
Merged Conversion Function Network

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

AIRFARE & CAR RENTAL RESULTS

Note: Bundling discount

MEDIATED QUERY

```
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:

Airline	Company	Total
British AIrways	Hertz	1747
British AIrways	National	1913
Lufthansa	Hertz	1775
Lufthansa	National	1747

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