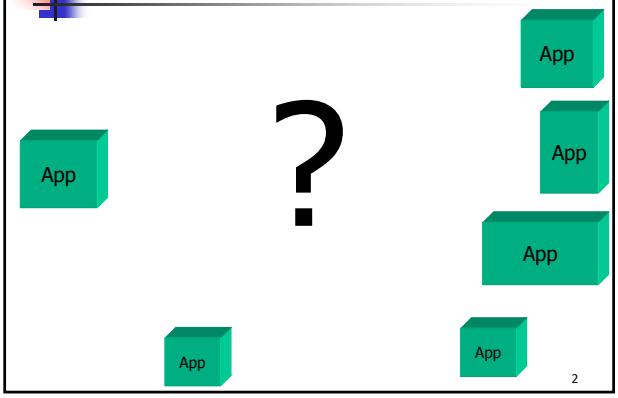
Semantic Data Exchange

Mariano Cilia
cilia@informatik.tu-darmstadt.de

Integration means Data Exchange



Motivation

- Interchange data among applications
  - Cooperate, interact, …
  - Fundamental for e-Commerce apps
- 1/2/02, how can I interpret this?

Motivation

- Interchange data among applications
  - Cooperate, interact, …
  - Fundamental for e-Commerce apps.
- 1/2/02
- 1234,00
- 0.5
- 23

Motivation

- Interchange data among applications
  - Cooperate, interact, …
  - Fundamental for e-Commerce apps.
- 1/2/02
- 1234,00
- 0.5
- 23
- calculate(21000, 3)

Motivation

- Interchange data among applications
  - Cooperate, interact, …
  - Fundamental for e-Commerce apps.
- 1/2/02
- 1234,00
- 0.5
- 23
- calculate(21000, 3)

Contextual information is required

Fundamental Semantic Heterogeneity

- Instance/entity identification problem
  - When two different information sources store information on an identical object, but do not share enough common information attributes to identify the object as the same
  - It cannot be solved algorithmically

Fundamental Semantic Heterogeneity (2)

- Two descriptions in different data sources have a similar meaning, but are quite the same
  - Neither data source (and schema) contains enough information to resolve the problem
    - E.g. prices in one DB include sales tax, while in a different DB do not
  - If data sources do not contain information to clarify the discrepancy, it cannot be resolved programmatically

Structural Semantic Heterogeneity

- When the same information is represented in two separate Apps in structurally different but formally equivalent ways. Two main reasons:
  - Normally, consequence of independent creation, design and evolution of autonomous Apps
  - Other reason, rich set of modeling constructors
- Spectrum of heterogeneity
  - Domain conflicts
  - Naming conflicts
  - Type conflicts
  - Structural conflicts

Domain conflicts

- Metadata specification differs and consequently conceptual schemas are different
  - The same entity is described differently in different domains
  - E.g. Paul is known as p123 in domain A and paul in domain B

Naming conflicts

- Objects may be represented in a different manner
  - The same attribute has different labels
  - E.g. Attribute name versus lastname

Type conflicts

- Systems represent low level atomic values differently
- Different types are used to describe related entities
- E.g. temperature may be of type integer in one system and of type float in another

Structural conflicts

- Data may be managed by different DBMSs
- A different data organization or structure is used to represent the same concepts
- E.g. An address type is represented as a structure or as a single attribute of type string

14

Overcoming Semantic Heterogeneity

- These heterogeneities can be overcome when
  - there is enough information in the metadata to clarify the meaning of each of the objects within the data source
- If it's not the case
  - Resolving these conflicts become difficult
  - and sometimes impossible

15

Overcoming: Domain conflicts

- By using semantic dictionaries
  - Must contain mapping between domains
    - Dictionary entry with
      - paul identifies p123 in domain A
      - p123 identifies paul in domain B
  - When objects cannot be mapped 1:1 across domains, a more complicated mapping mechanism must be used
    - This can result in information loss
    - E.g. Representation of grades and marks
      - Out of ten and A, B, C, … +, -

16

Overcoming: Naming conflicts

- Require mapping functions which simply change the labels of the attributes
  - Easy to overcome
- A naming conflict can be mistaken for a structural conflict
  - E.g. An attribute price may or may not include taxes

17

Overcoming: Type conflicts

- Usually can be resolved by applying conversion functions
- E.g. Programming languages provide functions for converting strings to integers

18

Overcoming: Structural confl.

- Involves decomposition or composition
  - E.g. The address type
    - represented in a structure composed into a single attribute
    - represented in a single string decomposed into a structure

19

Overcoming Semantic Heter.

- Ambiguity of data
  - Looking at data and metadata is sometimes not enough to fully understand its meaning
  - Completely removing ambiguity is unrealistic
- Semantic values
  - Facilitate integration of heterogeneous data
  - Help resolve many ambiguities in data

Data Integration - Issues

- Data from different sources/components is represented differently
- Different organizations/departments use different units and representation formats
- Many of the underlying assumptions about the meaning of a given data object are only implicit
- Context information is left implicit and consequently it is lost when crossing institutional boundaries

Why Semantic Metadata?

- The Internet as a global marketplace
- Business-to-Consumer:
  - interactive "point-and-click"
- Business-to-Business:
  - proprietary protocols
- Business-to-Business-to-Consumer:
  - need to extract and consolidate data for further electronic processing

Example – Travel Agency

Netscape: travel.html

File Edit View Go Communicator Help

Availability for FRANKFURT (FRA) to KENNEDY–NEW YORK (JFK)
Saturday, June 06 2000

Select	Airline	Flight	Departing		Arriving		Stops	Meal
			City	Time	City	Time		
	LH	400	FRA	10:35	JFK	13:00	0	S L

Price Per Adult (Economy Class): DEM 1826

Netscape: telep.html

File Edit View Go Communicator Help

Direct flight on **Saturday June 6, 2000**
Departing: FRA **Frankfurt**, Frankfurt Germany
Arriving at: JFK **John F. Kennedy Int'l Airport**, New York New York
Lufthansa, flight number **400**, departing **10:35** AM, arriving **1:00** PM
Class: **Y** – Economy Coach; Flight Dist.: **3850 Miles**

You can reserve this/these flight(s) at a fare of **$ 830** for one adult, incl. taxes.

Example – Travel Agency

Netscape: travel.html

File Edit View Go Communicator Help

Availability for FRANKFURT (FRA) to KENNEDY–NEW YORK (JFK)
Saturday, June 06 2000

Select	Airline	Flight	Departing		Arriving		Stops	Meal
			City	Time	City	Time		
	LH	400	FRA	10:35	JFK	13:00	0	S L

Price Per Adult (Economy Class): DEM 1826

Netscape: telep.html

File Edit View Go Communicator Help

Direct flight on **Saturday June 6, 2000**
Departing: FRA **Frankfurt**, Frankfurt Germany
Arriving at: JFK **John F. Kennedy Int'l Airport**, New York New York
Lufthansa, flight number **400**, departing **10:35** AM, arriving **1:00** PM
Class: **Y** – Economy Coach; Flight Dist.: **3850 Miles**

You can reserve this/these flight(s) at a fare of **$ 830** for one adult, incl. taxes.

Example – Travel Agency

Netscape: travel.html

File Edit View Go Communicator Help

Availability for FRANKFURT (FRA) to KENNEDY–NEW YORK (JFK)
Saturday, June 06 2000

Select	Airline	Flight	Departing		Arriving		Stops	Meal
			City	Time	City	Time		
	LH	400	FRA	10:35	JFK	13:00	0	S L

Price Per Adult (Economy Class): DEM 1826

Netscape: telep.html

File Edit View Go Communicator Help

Direct flight on **Saturday June 6, 2000**
Departing: FRA **Frankfurt**, Frankfurt Germany
Arriving at: JFK **John F. Kennedy Int'l Airport**, New York New York
Lufthansa, flight number **400**, departing **10:35** AM, arriving **1:00** PM
Class: **Y** – Economy Coach; Flight Dist.: **3850 Miles**

You can reserve this/these flight(s) at a fare of **$ 830** for one adult, incl. taxes.

The MIX Model

- **MIX**:

*"**M**etadata based **I**ntegration model for data **X**-change"*

- Combines two aspects:
  - *representation of data plus additional semantic metadata*
  - *flexible, self-describing data model for the representation of semi-structured data*

26

Ontology

An ontology is a formal specification
of a shared conceptualization
of a domain of interest

27

Ontologies in MIX

- Set of concepts and their relationships that model a given domain
- Ontology concept:
  - *is an abstraction of a set of real world phenomena*
  - *has a representation type associated that determines the physical representation of data of a given concept*
- Should be based on existing standards, but must be extensible

28

Simple Semantic Object

- A data item with additional metadata to support its interpretation:

< Distance, 3850, {<Unit,"mile">, <Scale, 1>} >

  - ***3850*** is the recorded data value
  - ***Distance*** denotes the ontology concept
  - ***{<Unit,"mile">, <Scale, 1>}*** represents the interpretation context of the value 3850

29

Complex Semantic Object

- A heterogeneous collection of semantic objects grouped under a corresponding concept

```
< FlightOffer, {
  < ClassOfService,        "Economy",        {<ClassOfServiceCode,
    "FullServiceClassName">} >,
  < Price,          1826,    {<Currency, "DEM">, <Scale, 1>} >,
  < FlightSegment, {
    < FlightNumber,          400 >,
    < AirlineIdentifier,     "LH",     {<AirlineIdentifierCode,
    "TwoLetterAirlineCode">} >,
    < DepartureDate,         "Jun 06 2000",     {<DateFormat, "Mon DD
    YYYY">} >,
    < DepartureTime,         "10:35",  {<TimeFormat, "HH:MM">} >,
    < DepartureAirport,      "FRA",    {<AirportIdentifierCode,
    "ThreeLetterAirportCode">} >,
    ...
    < Service,      "S",     {<ServiceCode, "OneLetterServiceCode">} >,
    < Service,      "L",     {<ServiceCode, "OneLetterServiceCode">} >      }
    >  } >
```

30

Conversion Function

- A function that converts semantic objects between different contexts

$\varphi_{Currency}$(*{ <Currency,"USD">}, < Price, 1826, {<Currency, "DEM">} >*)

= < Price, 830, {<Currency, "USD">} >

with "1 USD = 2.2 DEM"

- Provide a prerequisite for the integration of data from different sources

31

Semantic Equivalence

- Semantically equivalent objects represent the same information

  *< Distance, **3.850**, {<Unit, "mile">, <Scale,1000>} >*

  *< Distance, **3850**, {<Unit, "mile">, <Scale,1>} >*

- Determined through conversion to a common context and the comparison of their data values
- Depends in general on the context and conversion function used

32

Semantic Equivalence

- Semantically equivalent objects represent the same information

  *< Distance, **3850**, {<Unit, "mile">, <Scale,1>} >*

  *< Distance, **3850**, {<Unit, "mile">, <Scale,1>} >*

- Determined through conversion to a common context and the comparison of their data values
- Depends in general on the context and conversion function used

33

Semantic Identity

- Semantically identical objects represent information about the same real world object
- Complex objects: if all identifying attributes are semantically identical (recursive)
- Simple objects: if they are semantically equivalent

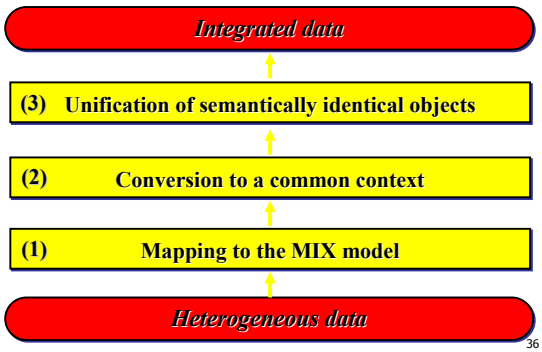
34

Representation & Domain-specific Ontologies

- Representation Ontologies
  - domain-independent physical representation basis
  - enables exchange and reuse of concepts
  - contains concepts like Numeric-Value, or Character-String
- Domain-specific Ontologies
  - refer to a concrete subject domain
  - provide a consistent conceptualization of this domain
  - contains concepts like FlightOffer, or Distance

35

Data Integration based on MIX



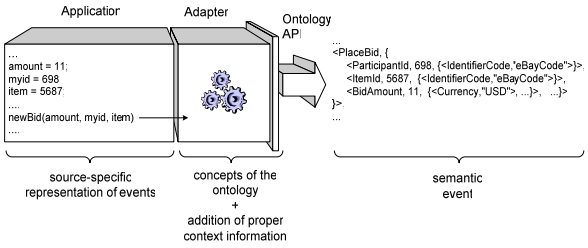
36

Ontology-based Infrastructure

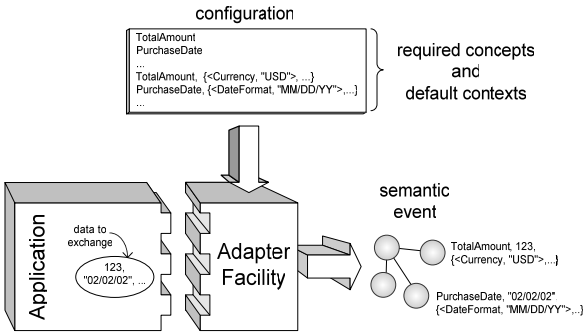
- In loosely-coupled (component-based) systems interfaces should consider the issues related with data interpretation
  - Specification of arguments must allow the inclusion of metadata in order to correctly interpret them
    - Calculate(<Price, 21000, {<Currency, "EUR">}>)
  - Arguments can be converted to the target context before using them

37

Adapters / Wrappers



Adapters / Wrappers (cont.)



Sem. Data Exchange - Summary

- Common interpretation basis for data
- Implicit modeling assumptions have to be made explicit
- Business-to-Business-to-Consumer:
  - need to extract, prepare and consolidate data for further electronic processing

Sem. Data Exchange – Summary (2)

- MIX:
  - allows to make explicit data semantics by using ontologies and metadata
  - supports integration, and automatic processing of Internet data
  - representation of data plus additional semantic metadata
  - flexible, self-describing data model for the representation of semi-structured data
  - conversion functions