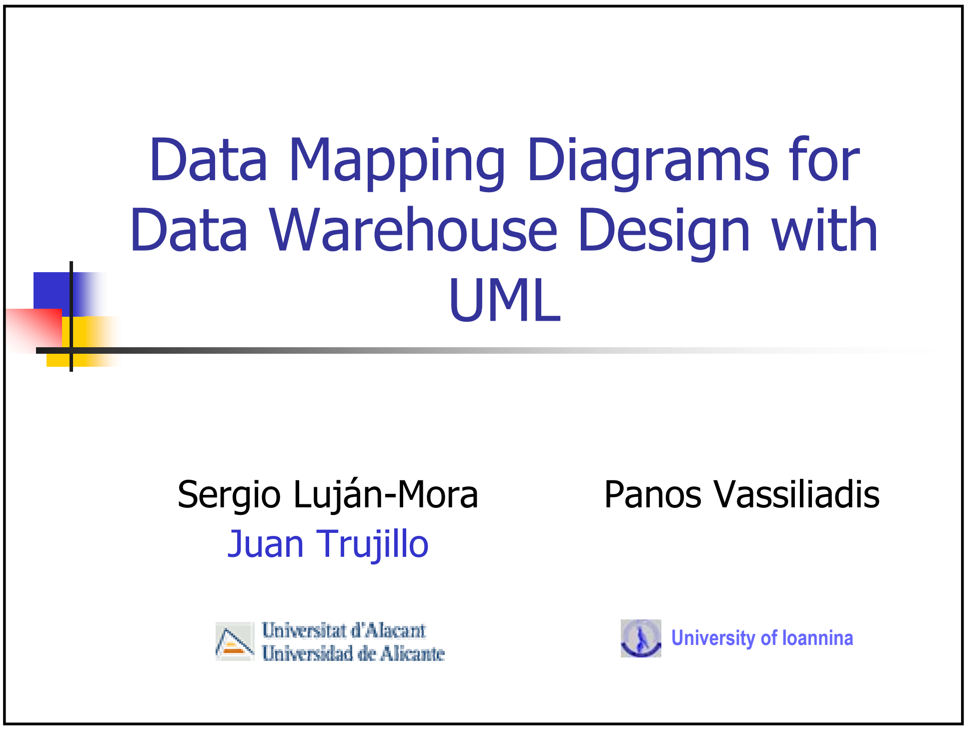
23rd International Conference on Conceptual Modeling (ER 2004), p. 191-204: Lecture Notes in Computer Science 3288, Shanghai (China), November 8-12 2004.



Data Mapping Diagrams for Data Warehouse Design with UML

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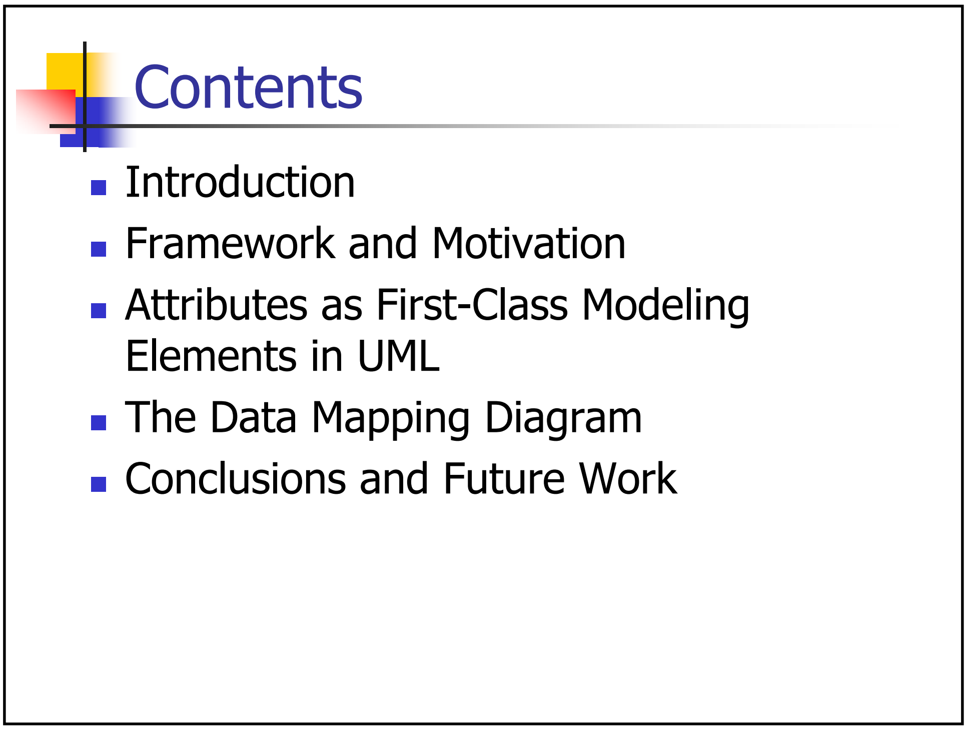

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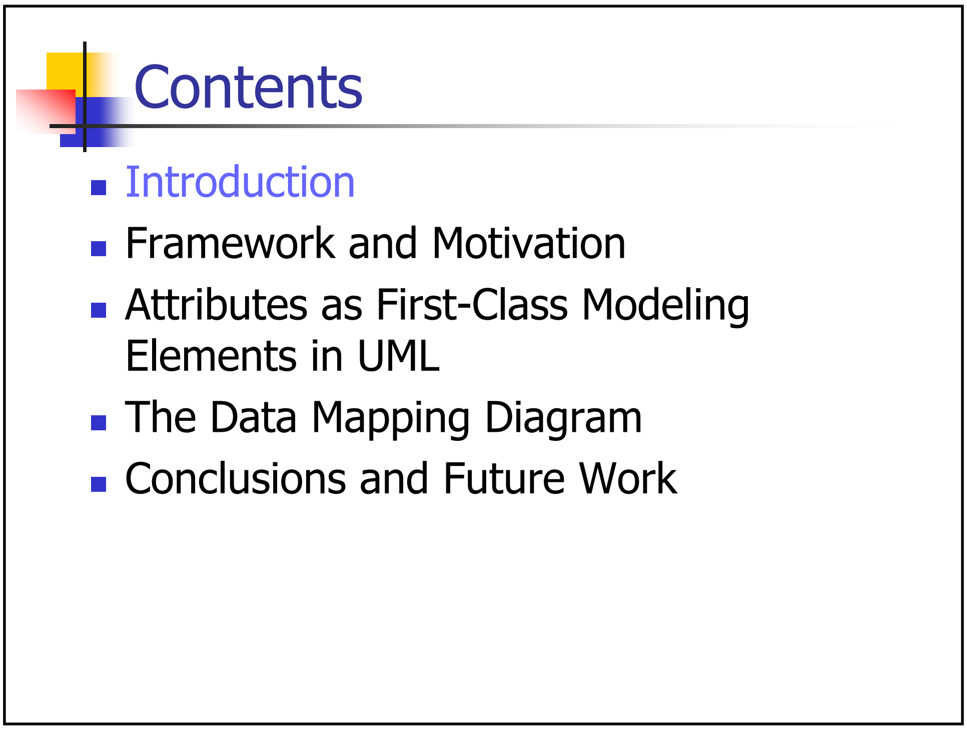
- Framework and Motivation
- Attributes as First-Class Modeling Elements in UML
- The Data Mapping Diagram
- Conclusions and Future Work



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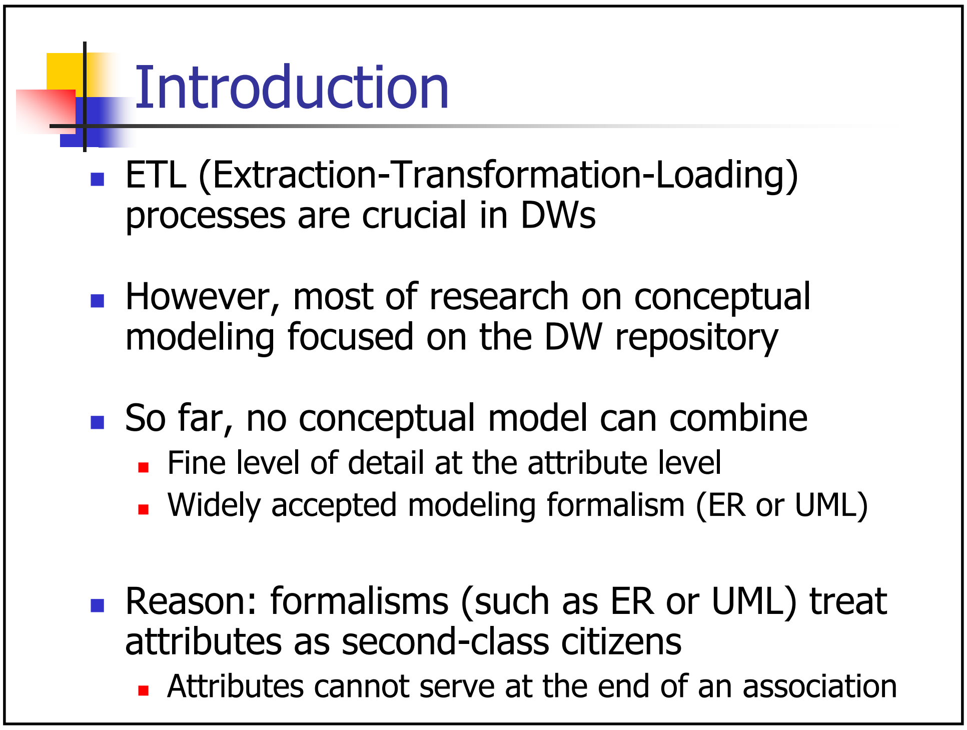

Introduction

- ETL (Extraction-Transformation-Loading) processes are crucial in DWs
- However, most of research on conceptual modeling focused on the DW repository
- So far, no conceptual model can combine
  - Fine level of detail at the attribute level
  - Widely accepted modeling formalism (ER or UML)
- Reason: formalisms (such as ER or UML) treat attributes as second-class citizens
  - Attributes cannot serve at the end of an association

Introduction

- Our proposal: a new UML diagram called the "*data mapping diagram*" to model ETL processes at various levels of detail
  - Attributes can be treated as first-class citizens (*FCML*)
  - UML is extended through the extension mechanisms
  - Attributes are formally mapped to proxy classes that can participate in associations for inter-attributes mappings
- KEY ASPECT
  - Integrated in a global approach for the modeling of DWs, based on the UML (ER02 & 03, UML02, IEEE)

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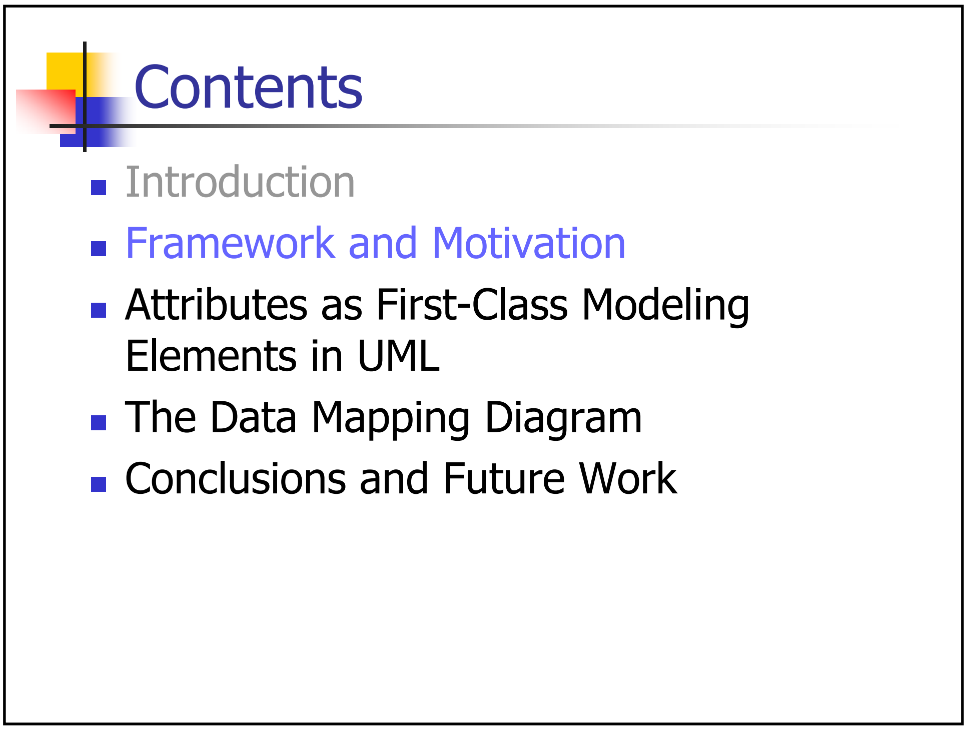

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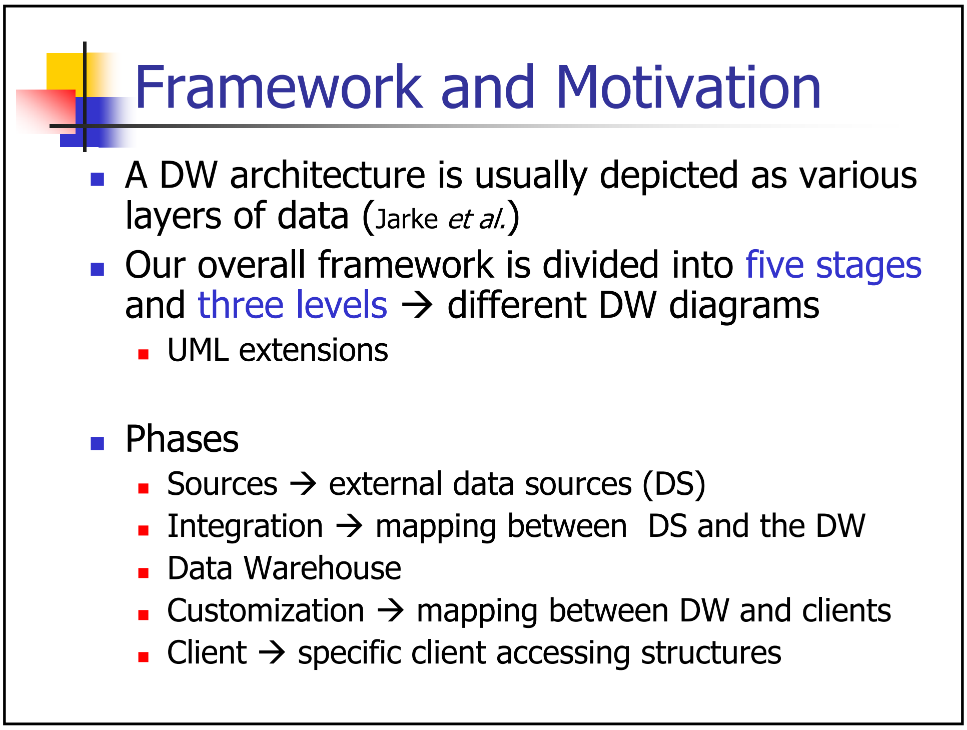


Framework and Motivation

- A DW architecture is usually depicted as various layers of data (Jarke *et al.*)
- Our overall framework is divided into five stages and three levels → different DW diagrams
  - UML extensions
- Phases
  - Sources → external data sources (DS)
  - Integration → mapping between DS and the DW
  - Data Warehouse
  - Customization → mapping between DW and clients
  - Client → specific client accessing structures

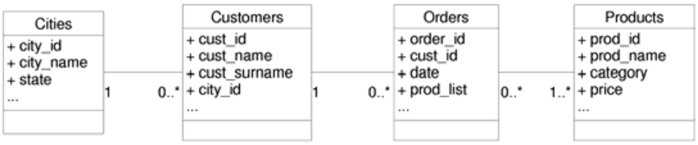
Framework and Motivation

- Levels
  - Conceptual → DW conceptual modeling
  - Logical → logical aspects of the DW (e.g. ETL)
  - Physical → e.g. storage of the ETL processes

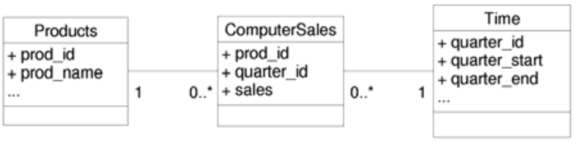
- Diagrams → Several UML profiles have been proposed. In this work: *Data mapping diagram*

- Motivating Example
  - Building a DW from the retail system of a company

Framework and Motivation

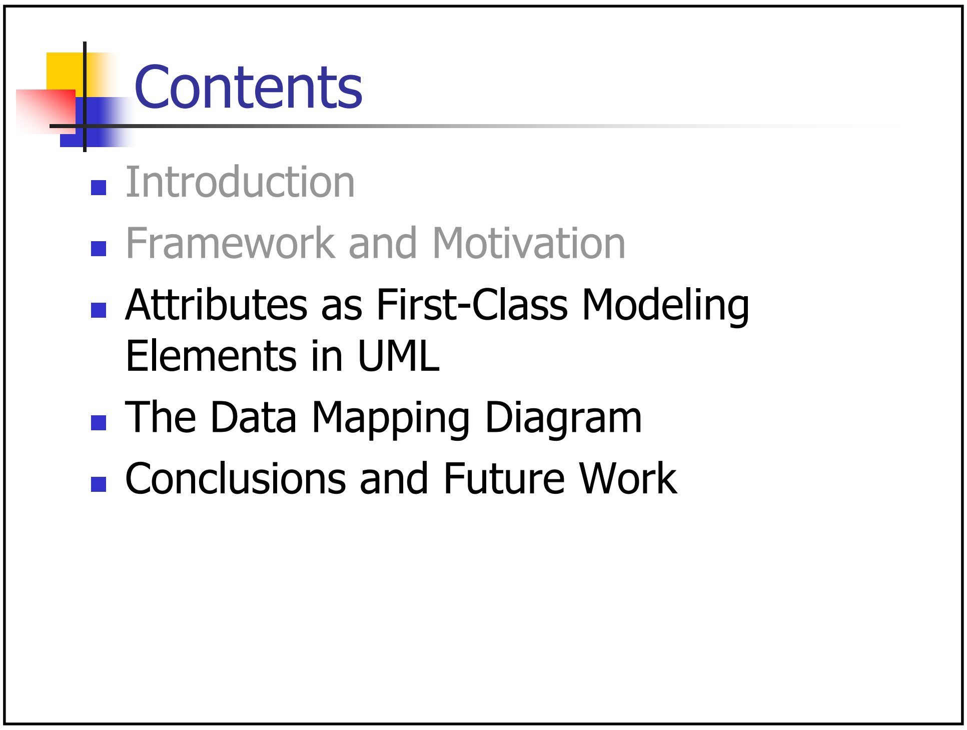


Source Conceptual Schema (SCS)



Data Warehouse Conceptual Schema (DWCS)

- Data Mapping Diagram shows the relationships between the data sources and the DW, and between the DW and client's structures



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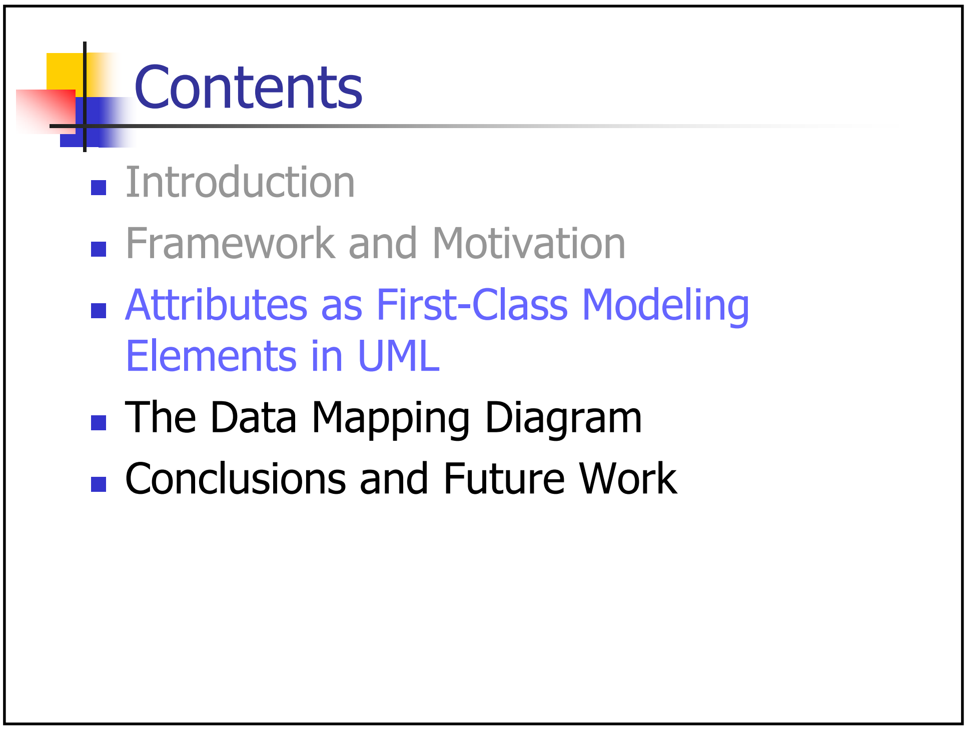

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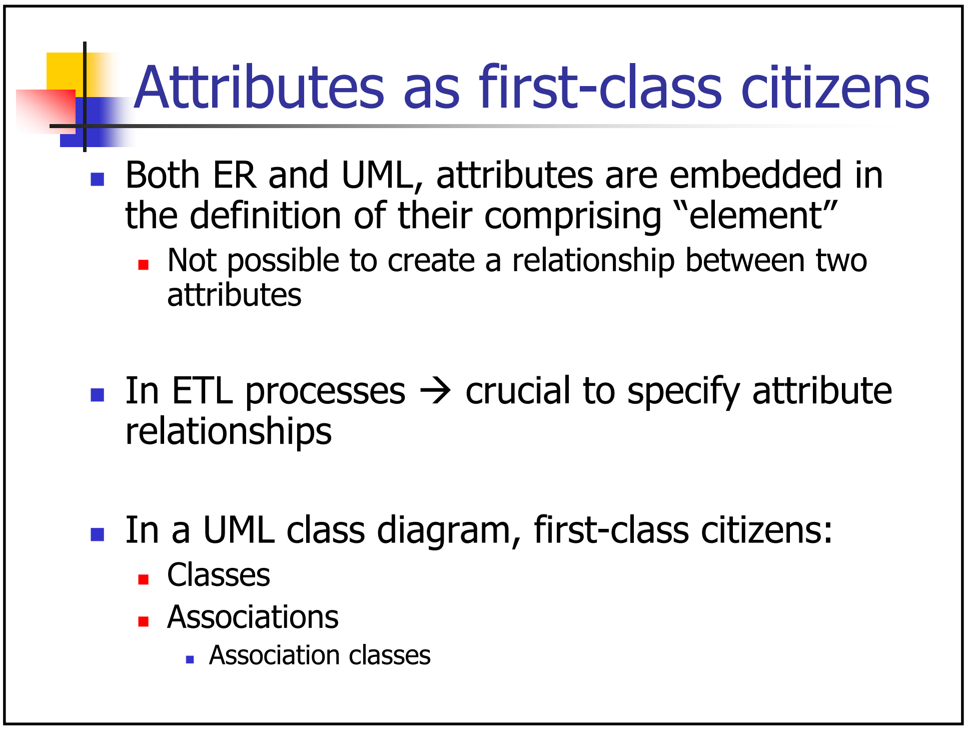
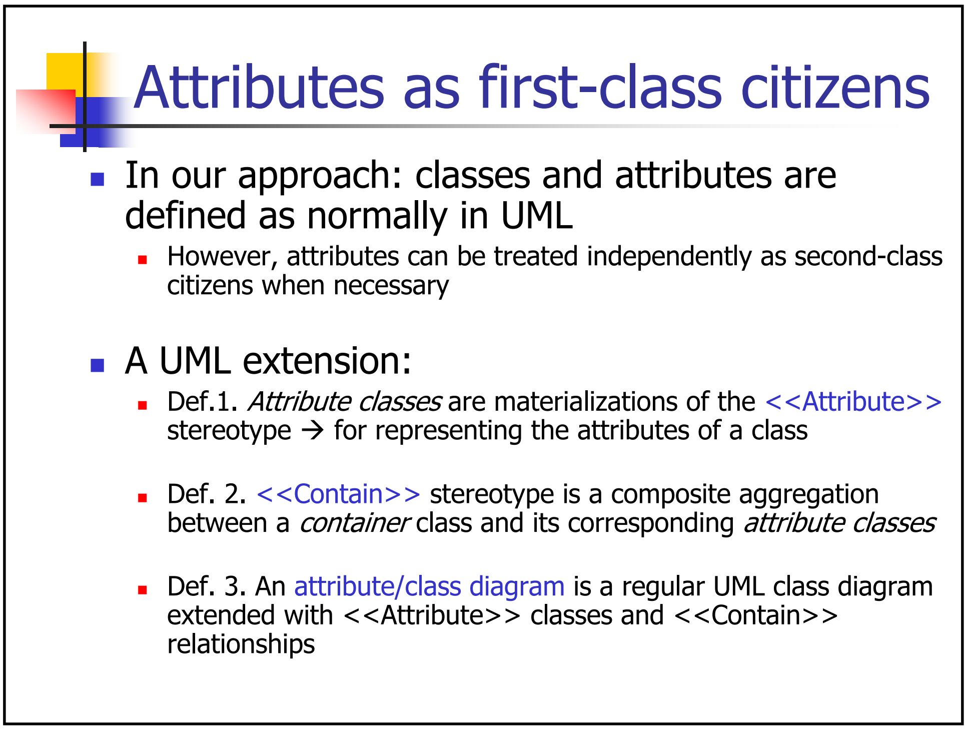


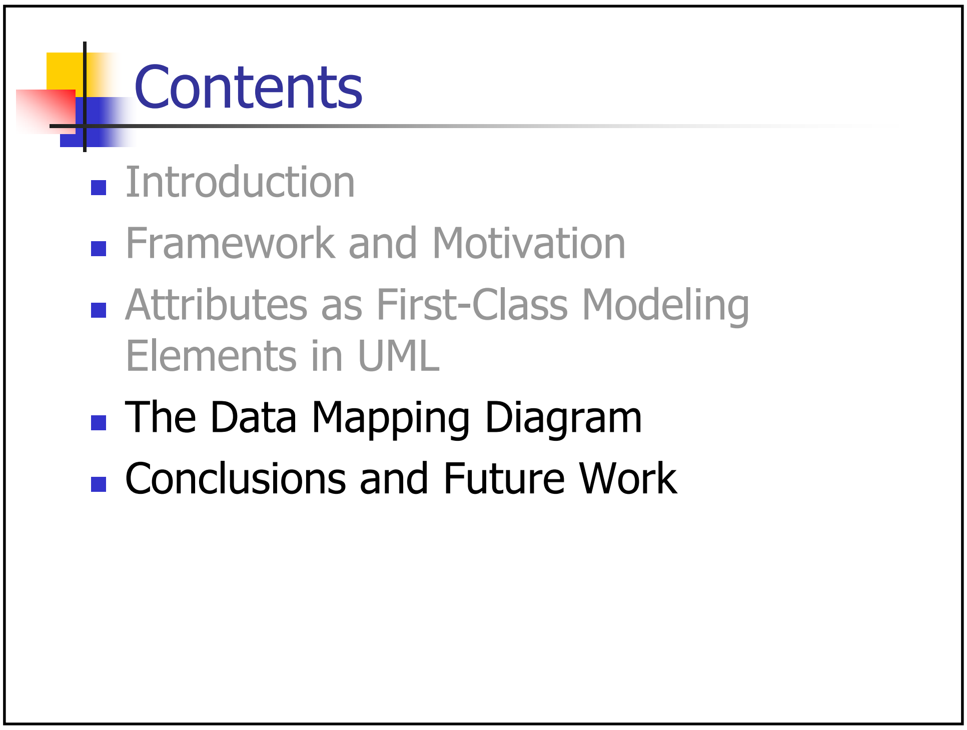
Attributes as first-class citizens

- Both ER and UML, attributes are embedded in the definition of their comprising "element"
  - Not possible to create a relationship between two attributes
- In ETL processes → crucial to specify attribute relationships
- In a UML class diagram, first-class citizens:
  - Classes
  - Associations
    - Association classes



Attributes as first-class citizens

- In our approach: classes and attributes are defined as normally in UML
  - However, attributes can be treated independently as second-class citizens when necessary
- A UML extension:
  - Def.1. *Attribute classes* are materializations of the <<Attribute>> stereotype → for representing the attributes of a class
  - Def. 2. <<Contain>> stereotype is a composite aggregation between a *container* class and its corresponding *attribute classes*
  - Def. 3. An attribute/class diagram is a regular UML class diagram extended with <<Attribute>> classes and <<Contain>> relationships



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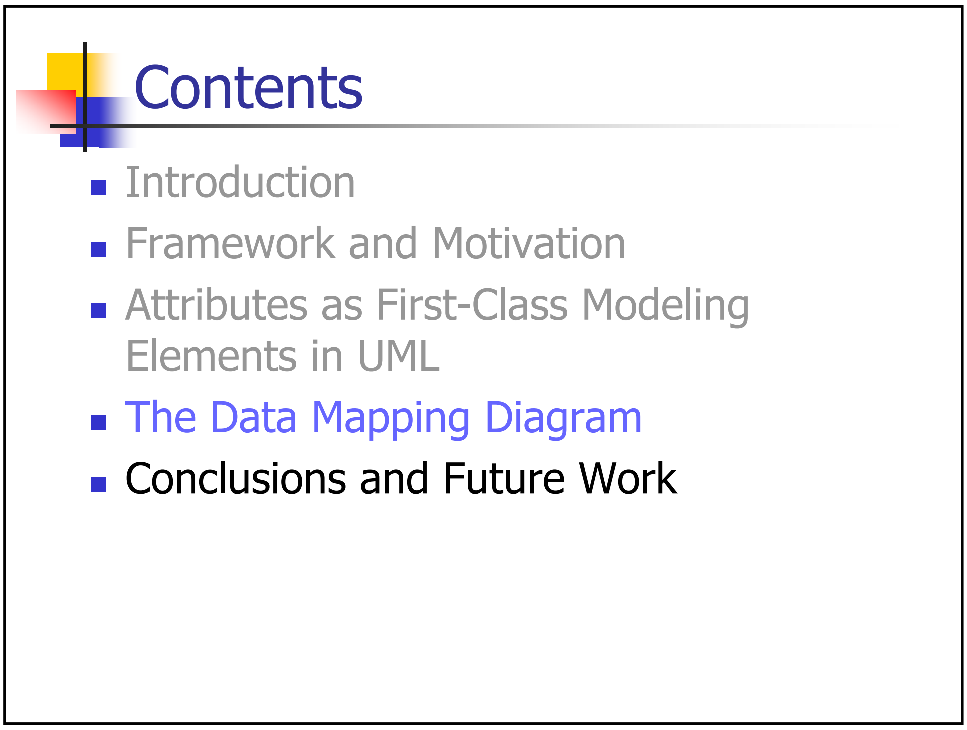

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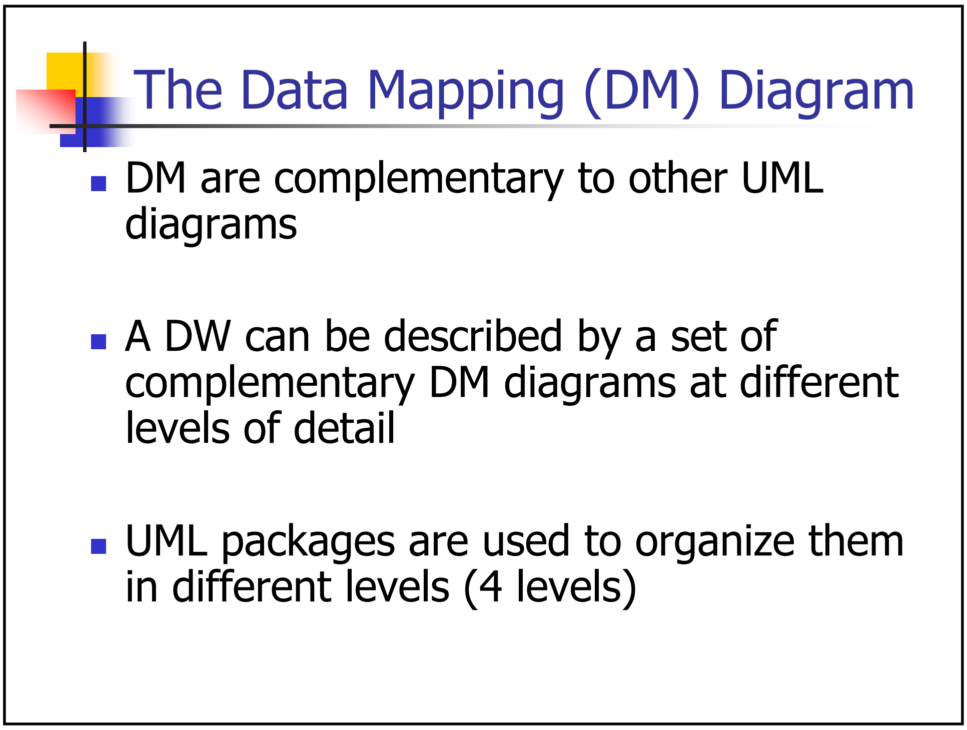
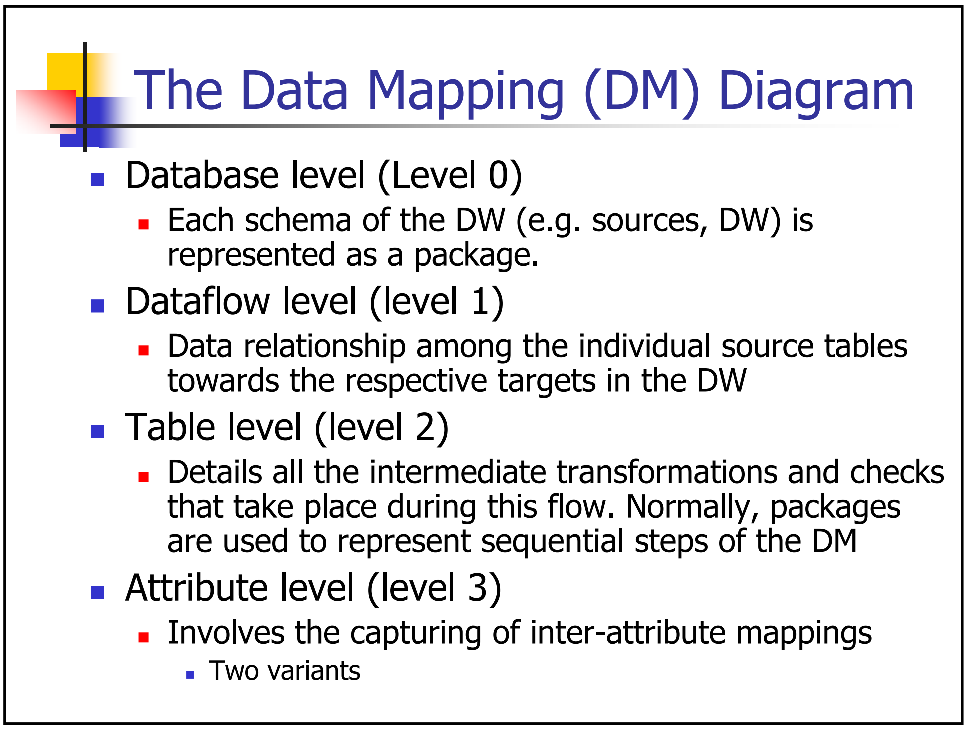


The Data Mapping (DM) Diagram

- DM are complementary to other UML diagrams
- A DW can be described by a set of complementary DM diagrams at different levels of detail
- UML packages are used to organize them in different levels (4 levels)

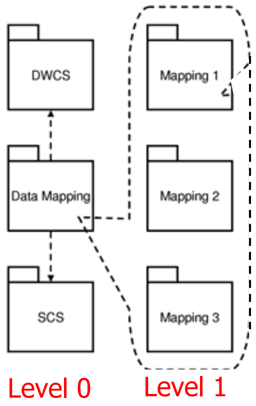


The Data Mapping (DM) Diagram

- Database level (Level 0)
  - Each schema of the DW (e.g. sources, DW) is represented as a package.
- Dataflow level (level 1)
  - Data relationship among the individual source tables towards the respective targets in the DW
- Table level (level 2)
  - Details all the intermediate transformations and checks that take place during this flow. Normally, packages are used to represent sequential steps of the DM
- Attribute level (level 3)
  - Involves the capturing of inter-attribute mappings
    - Two variants

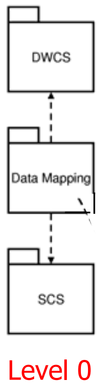
The Data Mapping Diagram

- Database and dataflow diagrams (0 and 1) use traditional UML elements
  - Packages for modeling data relationships
  - Dependency relationships between packages



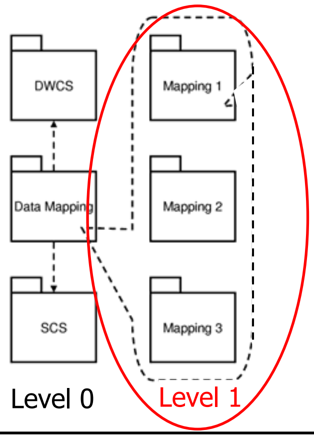
The Data Mapping Diagram

- Level 0: a simple relationship among the DWCS and the SCS exists
  - Captured by a single Data Mapping package and these three design elements



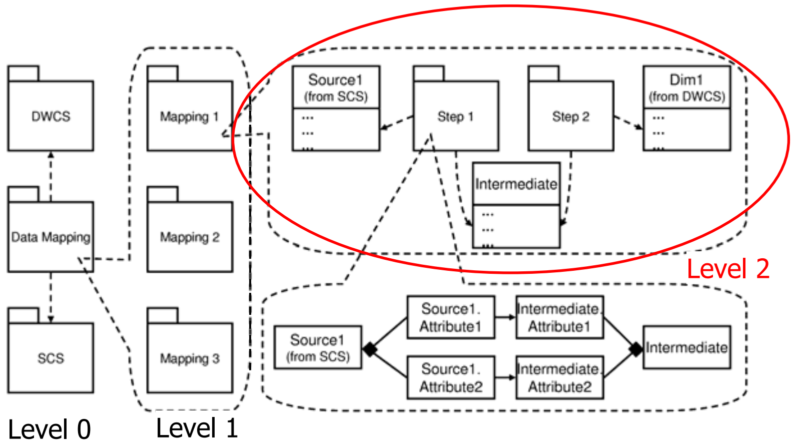
The Data Mapping Diagram

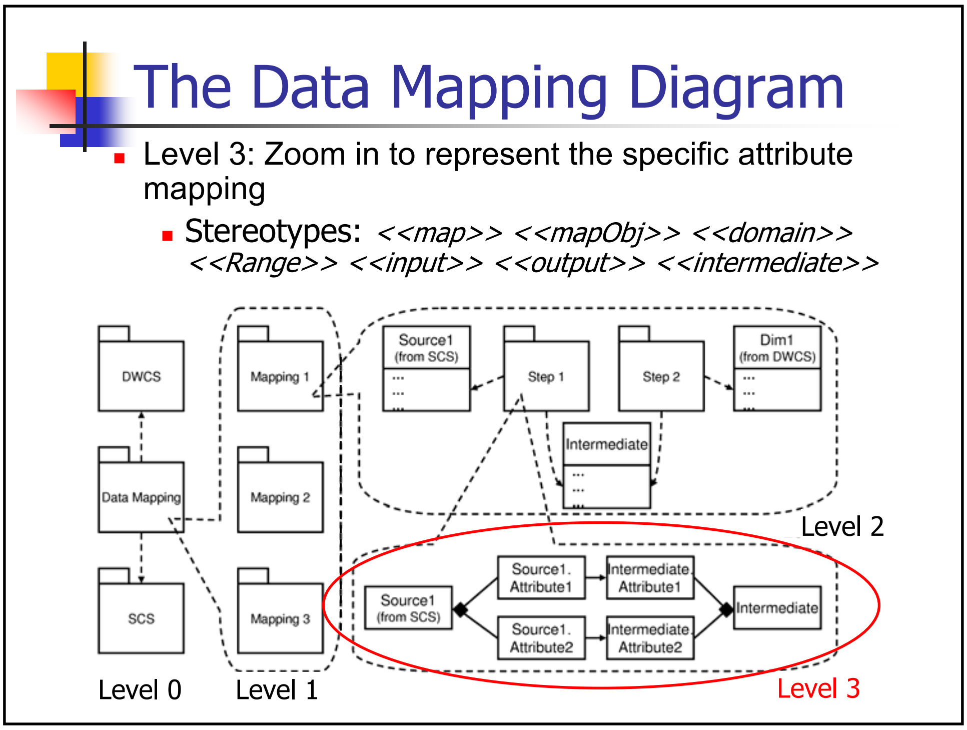
- Level 1: three particular tables to populate → three main scenarios for populating the DW
  - Captured by three Data Mapping packages



The Data Mapping Diagram

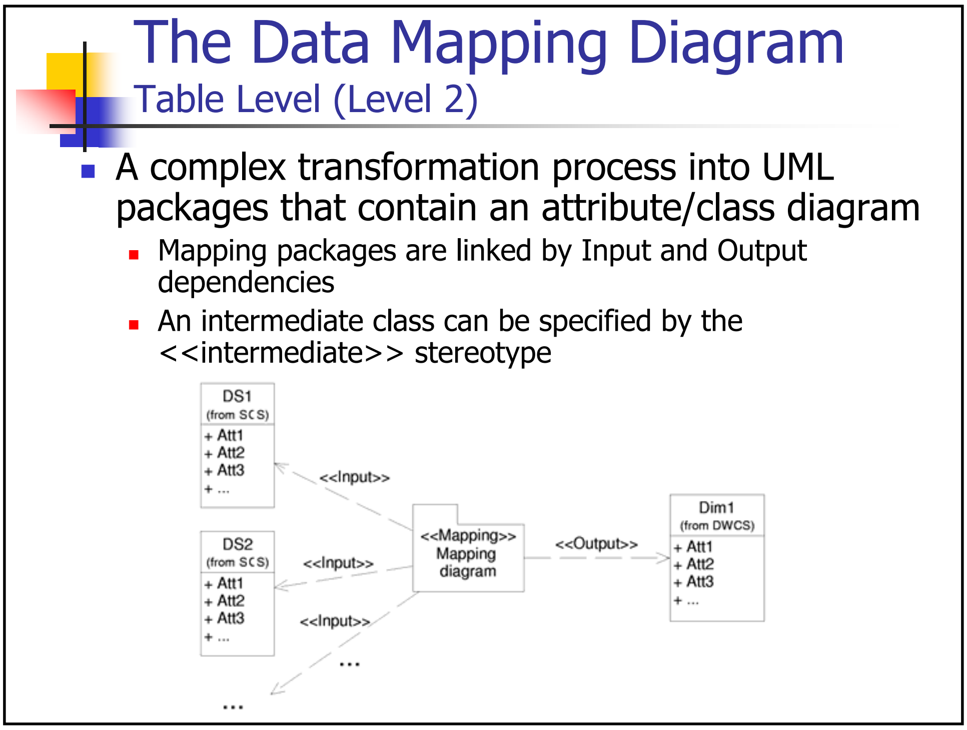
- Level 2: Zoom in to represent the particular transformation/mapping
  - Stereotypes: *<<mapping>> <<input>> <<output>>*





The Data Mapping Diagram

- Level 3: Zoom in to represent the specific attribute mapping
  - Stereotypes: *<<map>> <<mapObj>> <<domain>> <<Range>> <<input>> <<output>> <<intermediate>>*



The Data Mapping Diagram

Table Level (Level 2)

- A complex transformation process into UML packages that contain an attribute/class diagram
  - Mapping packages are linked by Input and Output dependencies
  - An intermediate class can be specified by the <<intermediate>> stereotype

The Data Mapping Diagram

Attribute Level (Level 3)

- Relationships between the attributes of the classes involved in a data mapping. Two variants:
  - Compact Variant: relationships represented as *associations*, and the semantic of the mapping described in a UML *note*
    - Less cluttered diagrams, but less semantic impact
  - Formal variant: relationships represented by a *mapping object*, and the semantic of the mapping described in a *tag definition*
    - More modeling elements, but more formal semantics

The Data Mapping Diagram

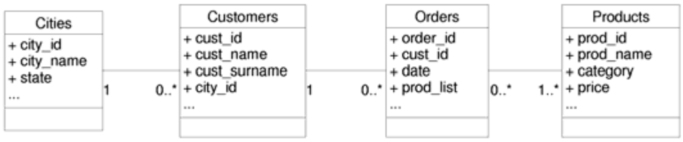
Attribute Level (Level 3). Compact variant

- Elements are imported from other diagrams
- Attributes are represented as <<Attribute>> classes
- <<Attribute>> classes connected by association relationships and the navigability
- Association relationships adorned with the stereotype <<Map>>
- UML notes to specify how the target attribute of the DW is obtained from the source one

The Data Mapping Diagram

Motivating example

- Calculate the quarterly sales of the products belonging to the computer category



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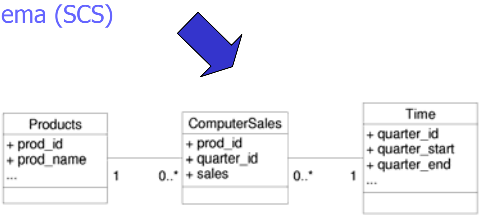
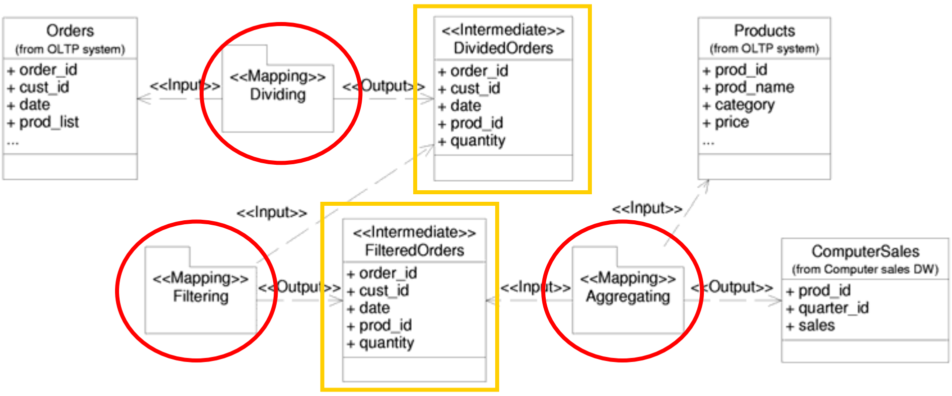


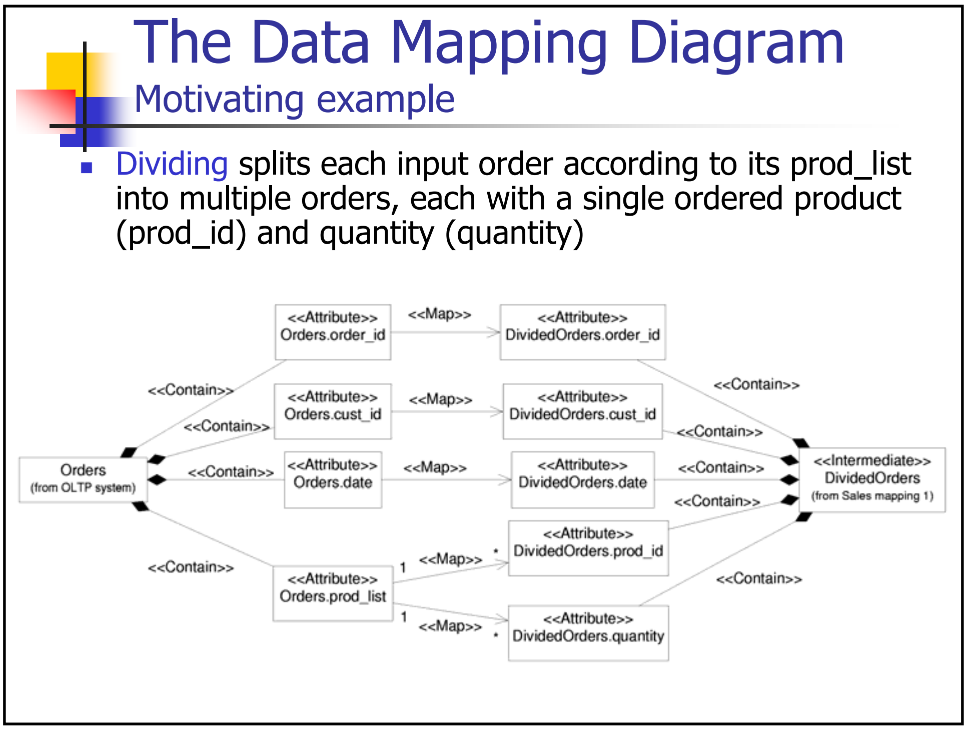
Data Warehouse Conceptual Schema (DWCS)

The Data Mapping Diagram

Motivating example

- Level 2 of the data mapping diagram



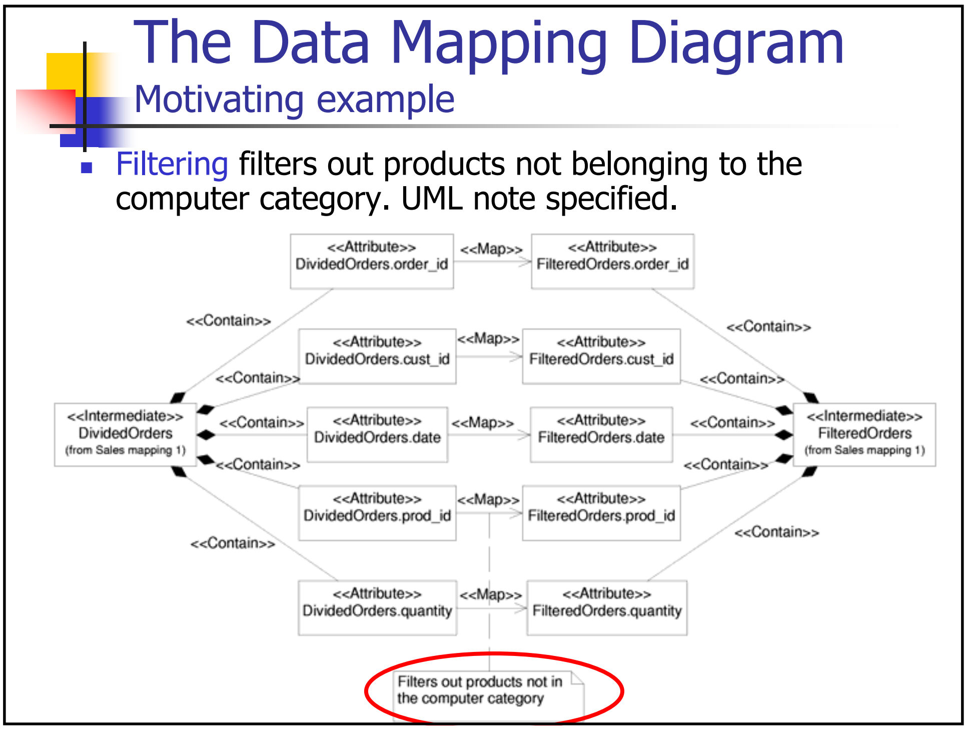


The Data Mapping Diagram

Motivating example

- Dividing splits each input order according to its prod_list into multiple orders, each with a single ordered product (prod_id) and quantity (quantity)

<<Attribute>> Orders.order_id
<<Map>>
<<Attribute>> DividedOrders.order_id
<<Contain>>
<<Attribute>> Orders.cust_id
<<Map>>
<<Attribute>> DividedOrders.cust_id
<<Contain>>
<<Contain>>
<<Contain>>
Orders (from OLTP system)
<<Contain>>
<<Attribute>> Orders.date
<<Map>>
<<Attribute>> DividedOrders.date
<<Contain>>
<<Intermediate>> DividedOrders (from Sales mapping 1)
<<Contain>>
<<Attribute>> DividedOrders.prod_id
<<Contain>>
1
<<Map>>
*
<<Attribute>> Orders.prod_list
<<Contain>>
1
<<Map>>
*
<<Attribute>> DividedOrders.quantity

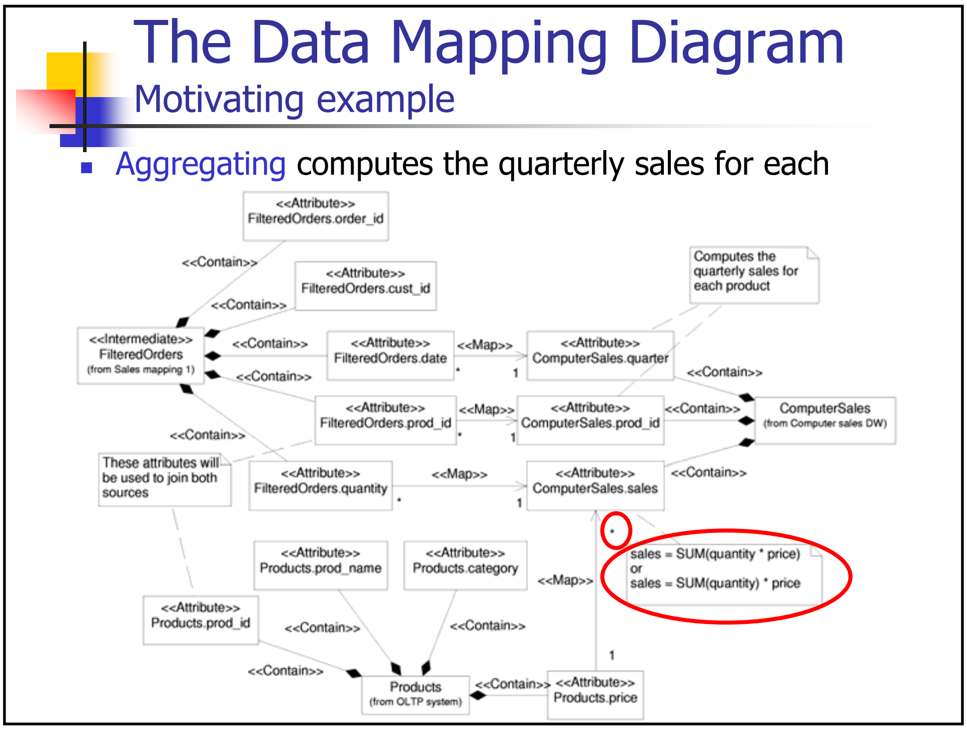


The Data Mapping Diagram

Motivating example

- Filtering filters out products not belonging to the computer category. UML note specified.

<<Attribute>> DividedOrders.order_id
<<Map>>
<<Attribute>> FilteredOrders.order_id
<<Contain>>
<<Contain>>
<<Attribute>> DividedOrders.cust_id
<<Map>>
<<Attribute>> FilteredOrders.cust_id
<<Contain>>
<<Contain>>
<<Intermediate>> DividedOrders (from Sales mapping 1)
<<Contain>>
<<Attribute>> DividedOrders.date
<<Map>>
<<Attribute>> FilteredOrders.date
<<Contain>>
<<Intermediate>> FilteredOrders (from Sales mapping 1)
<<Contain>>
<<Contain>>
<<Attribute>> DividedOrders.prod_id
<<Map>>
<<Attribute>> FilteredOrders.prod_id
<<Contain>>
<<Contain>>
<<Attribute>> DividedOrders.quantity
<<Map>>
<<Attribute>> FilteredOrders.quantity
Filters out products not in the computer category

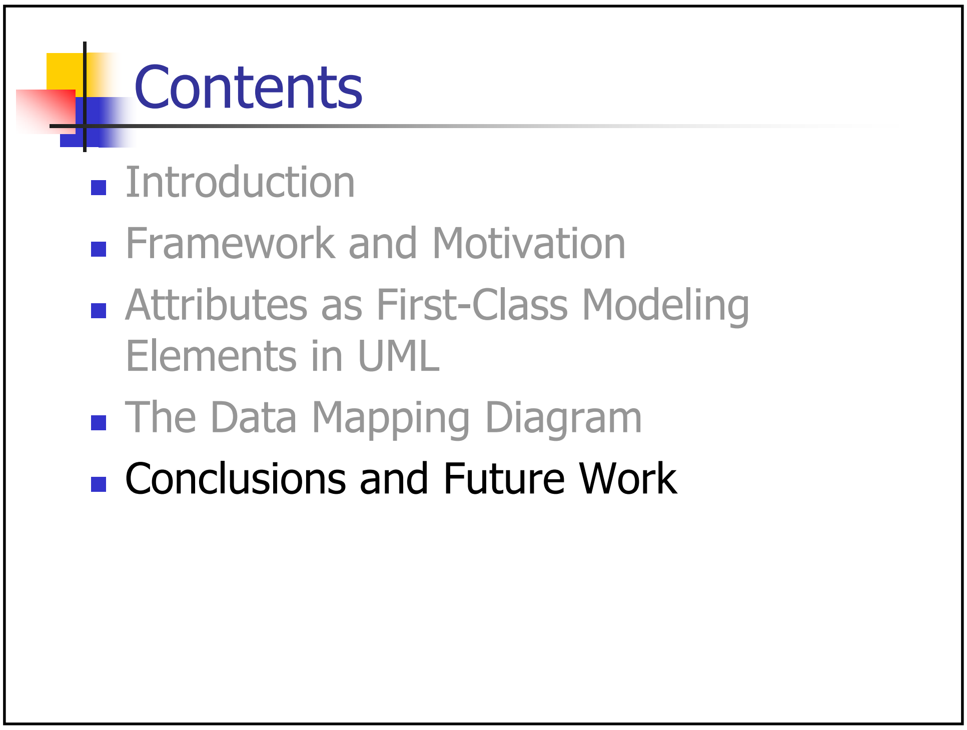


The Data Mapping Diagram

Motivating example

- Aggregating computes the quarterly sales for each

<<Attribute>> FilteredOrders.order_id
<<Contain>>
<<Attribute>> FilteredOrders.cust_id
<<Contain>>
<<Intermediate>> FilteredOrders (from Sales mapping 1)
<<Contain>>
<<Attribute>> FilteredOrders.date
<<Map>>
<<Attribute>> ComputerSales.quarter
Computes the quarterly sales for each product
<<Contain>>
<<Attribute>> FilteredOrders.prod_id
<<Map>>
<<Attribute>> ComputerSales.prod_id
<<Contain>>
ComputerSales (from Computer sales DW)
<<Contain>>
These attributes will be used to join both sources
<<Attribute>> FilteredOrders.quantity
<<Map>>
<<Attribute>> ComputerSales.sales
<<Contain>>
*
sales = SUM(quantity * price) or sales = SUM(quantity) * price
<<Attribute>> Products.prod_name
<<Attribute>> Products.category
<<Map>>
<<Attribute>> Products.prod_id
<<Contain>>
<<Contain>>
<<Contain>>
Products (from OLTP system)
<<Contain>>
<<Attribute>> Products.price
1



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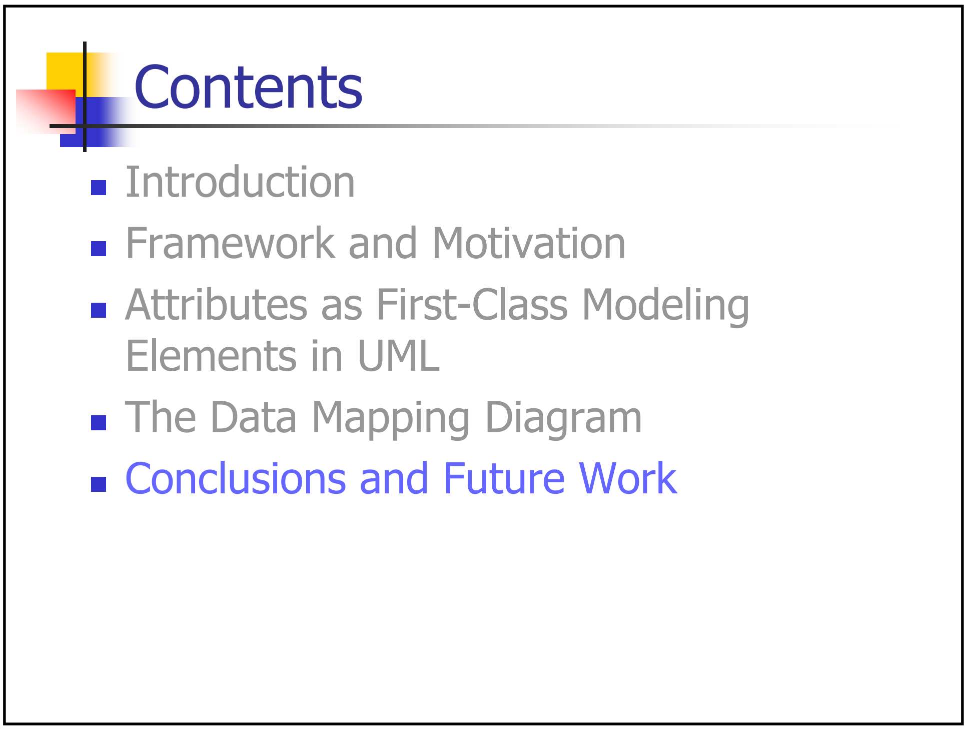

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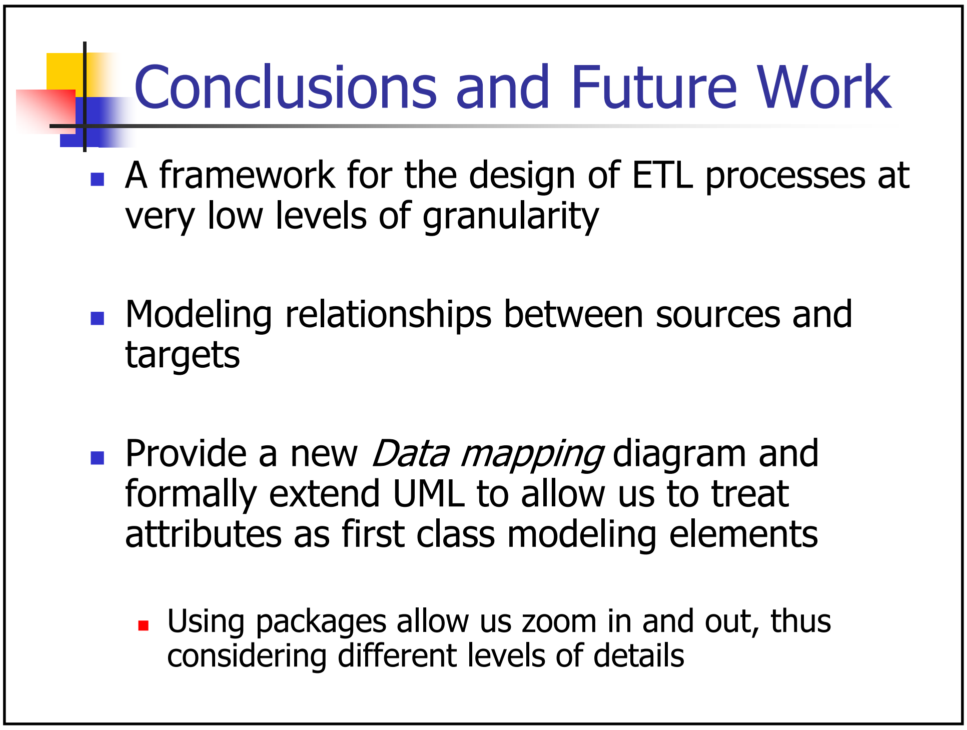

Conclusions and Future Work

- A framework for the design of ETL processes at very low levels of granularity
- Modeling relationships between sources and targets
- Provide a new *Data mapping* diagram and formally extend UML to allow us to treat attributes as first class modeling elements
  - Using packages allow us zoom in and out, thus considering different levels of details

Conclusions and Future Work

- Immediate future work
  - Implementing the Compact approach
    - Considering more formal semantics instead of notes
  - A complete implementation mapping in a target platform and existing ETL tools (e.g. DB2 Center, OWB and so on)
- Further work
  - This approach can be applied to the modeling of XML documents, specification of Web services or materialization of database views.

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