Lecture 04

Data Warehouse Architecture (cont'd.)

Summary – last week

- Last week:
  - Lifecycle and phases
  - DW Operations
  - DW Architecture
    - Basic Architecture
    - Storage Architecture

- This week:
  - Tier Architecture
  - Distributed DW
  - DW Data Modeling

Acknowledgment - Thanks to Wolf-Tilo Balke and Silviu Homoceanu - TU Braunschweig for the slides

Tier Architecture

- Popular DW architectures
  - Generic Two-Tier Architecture
  - Independent Data Mart
  - Dependent Data Mart and Operational Data Store
  - Logical Data Mart and Active Warehouse
  - Three-Tier Architecture
- Other
  - One-Tier Architecture
  - N-Tier Architecture
  - Web-based Architecture

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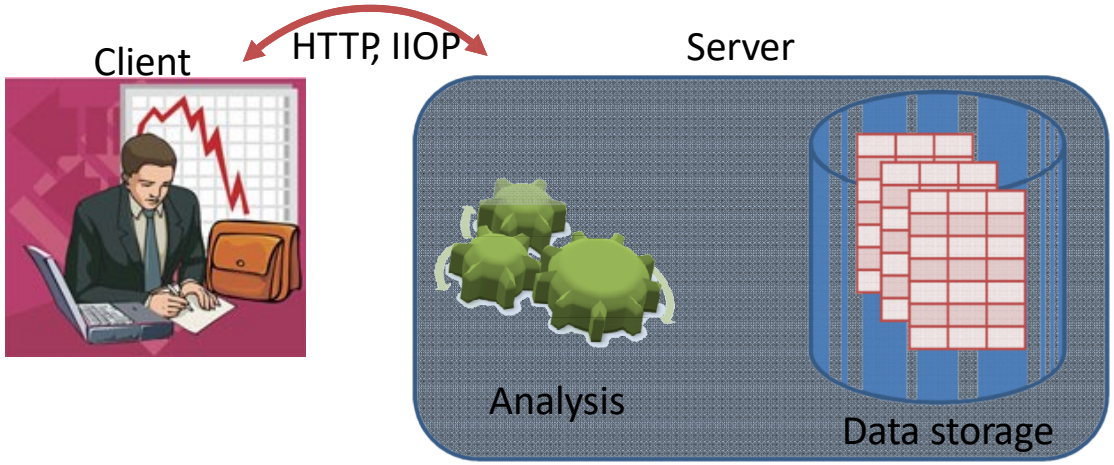
Layered Architecture

- Data **analysis** comes in two flavors
  - Depending on the execution place of the analysis
    - Thin Client
      - Analytics are executed on the server
      - Client just displays
      - This architecture fits well for Internet/Intranet DW access



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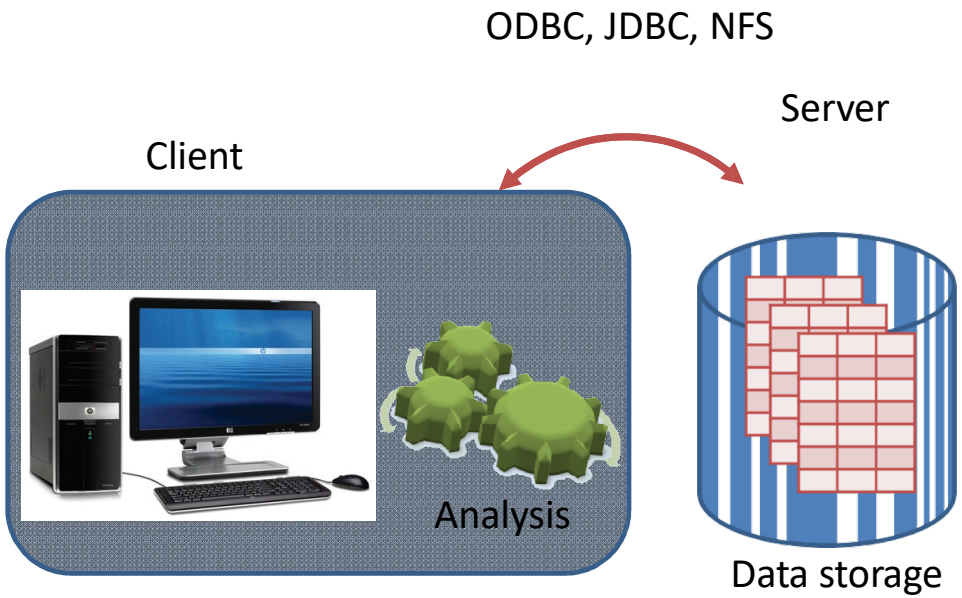
Layered Architecture (cont'd.)

- Fat Client
  - The server just delivers the data
  - Analytics are executed on the client
  - Communication between client and server must be able to sustain large data transfers



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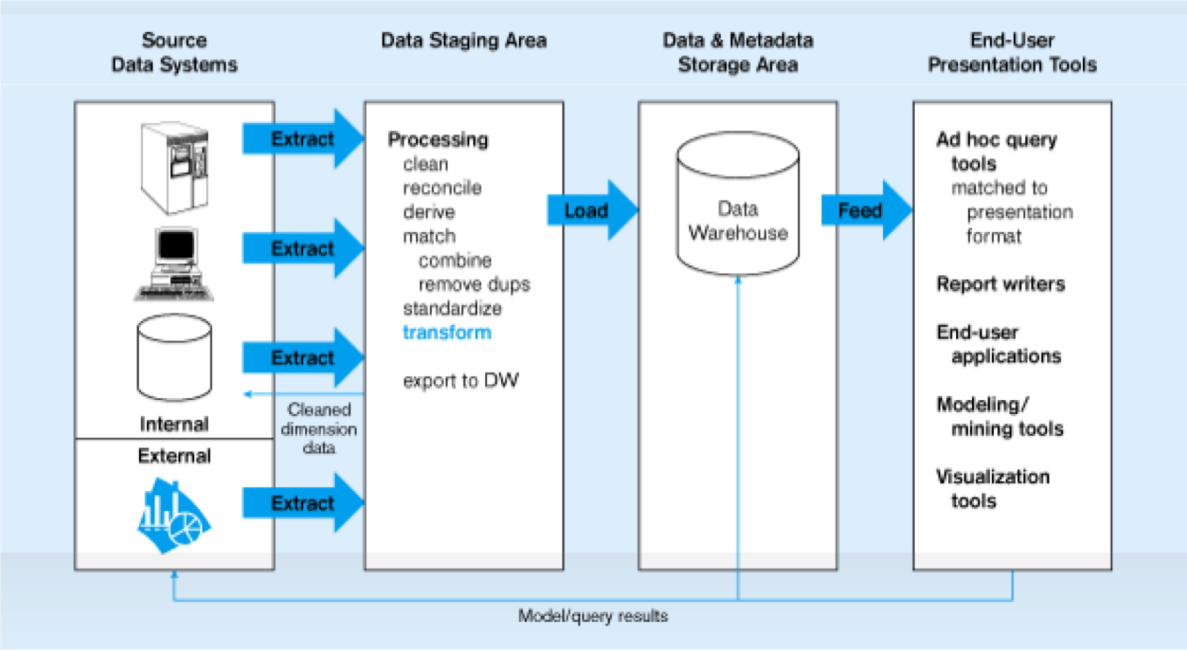
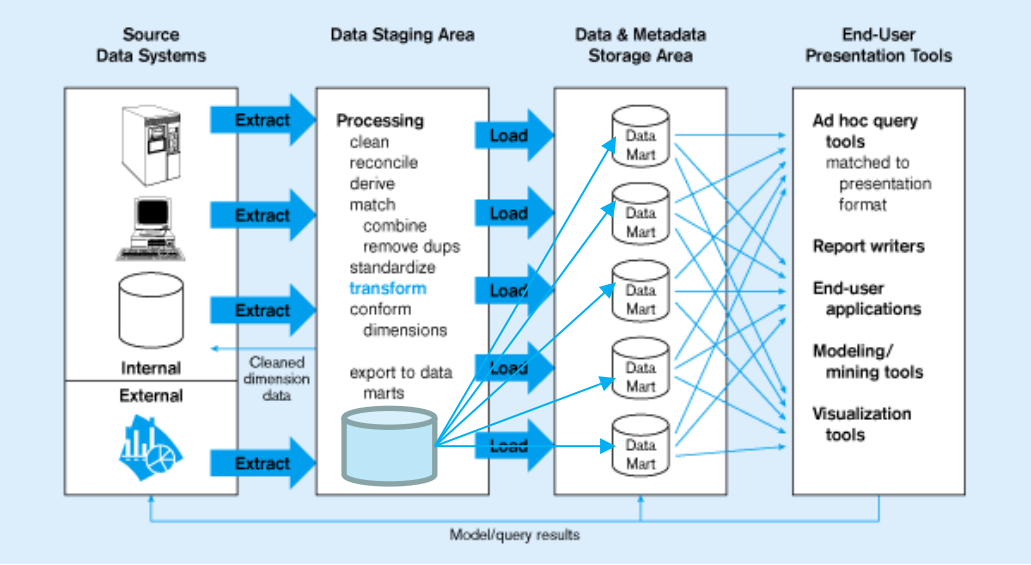
Layered Architecture (cont'd.)

- Generic Two-Tier Architecture
  - Data is not completely current in the DW
  - Periodic extraction



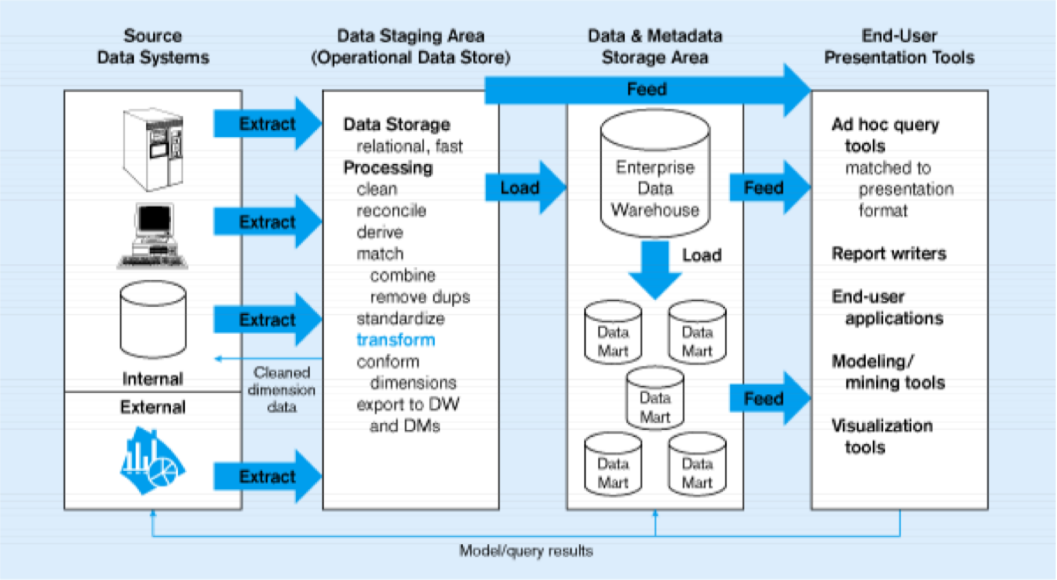
Layered Architecture (cont'd.)

- Independent Data Mart
  - Mini warehouses – limited in scope
  - Separate ETL for each independent Data Mart
  - High Data Marts access complexity



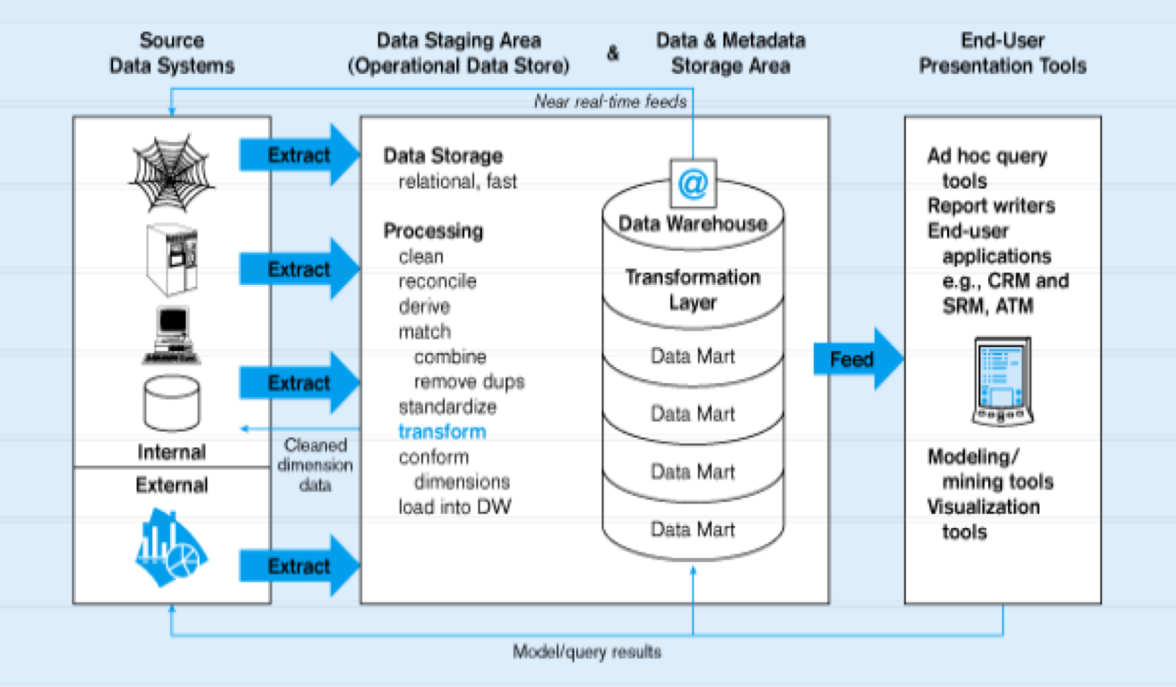
Layered Architecture (cont'd.)

- **Dependent Data Mart** and Operational Data Store
  - –Single ETL for the DW
  - – Data Marts are loaded from the DW
  - –More simple data access than in the previous case



Layered Architecture (cont'd.)

- **Logical Data Mart** and Active Warehouse
  - The ETL is near real-time
  - Data Marts are *not* separate databases, but logical views of the DW



DW vs. Data Marts

Scope	
DW	Data Marts
Application independent	Specific DSS application
Centralized,	Decentralized by user area
Planned	Organic, possibly not planned

Data	
DW	Data Marts
Historical, detailed, summarized	Some history, detailed, summarized
Lightly denormalized	Highly denormalized

Subjects	
DW	Data Marts
Multiple subjects	One central subject

Sources	
DW	Data Marts
Many internal and external sources	Few internal and external sources

Other characteristics	
DW	Data Marts
Flexible	Restrictive
Data-oriented	Project oriented
Long life	Short life
Large	Start small, becomes large
Single complex structure	Multiple, semi-complex structure, together complex

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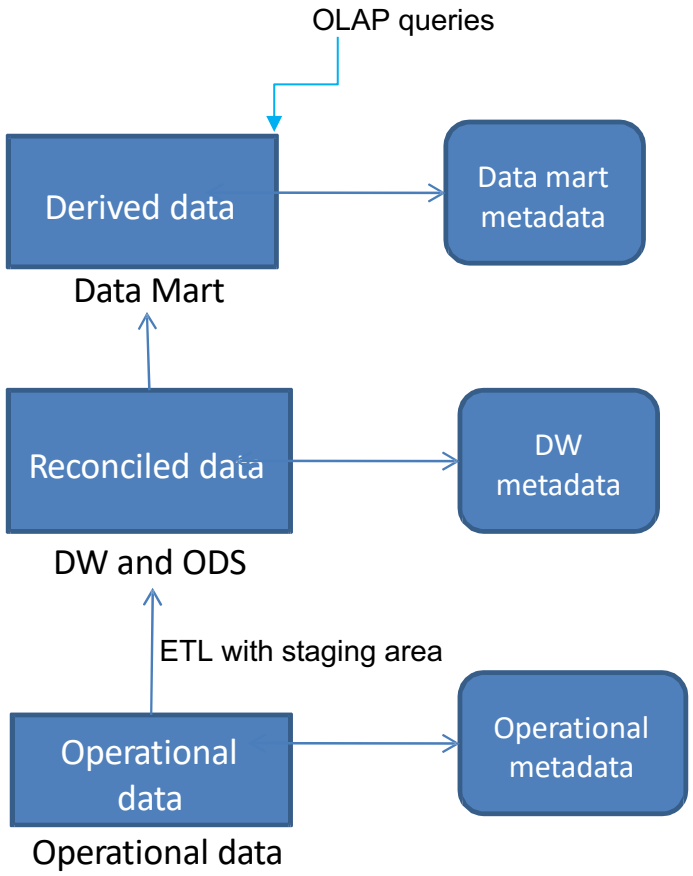
Layered Architecture (cont'd.)

- Generic Three-Tier Architecture
  - Derived data
    - Data that had been selected, formatted, and aggregated for DSS support
  - Reconciled data
    - Detailed, current data intended to be the single, authoritative source for all decision support



Layered Architecture (cont'd.)

- One-Tier Architecture
  - Theoretically possible
  - Might be interesting for mobile applications
- N-Tier Architecture
  - Higher tier architecture is also possible
    - But the complexity grows with the number of tier-interfaces
- Web-based Architecture
  - Advantages:
    - Usage of existing software, reduction of costs, platform independence
  - Disadvantages:
    - Security issues: data encryption/user access and identification

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Distributed DW

- In most cases the economics and technology greatly favor a single **centralized DW**
- But in some cases, distributed DW make sense
- Types of **distributed DW**
  - Geographically distributed
    - Local DW instances of global DW
  - Technologically distributed DW
    - Logically one DW but data is stored on multiple stores

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Distributed DW (cont'd.)

- Geographically distributed
  - In the case of corporations spread around the world
    - Information is needed both locally and globally
  - A distributed DW makes sense
    - When much processing occurs at the local level
    - Even though local branches report to the same balance sheet, the local organizations are their own companies

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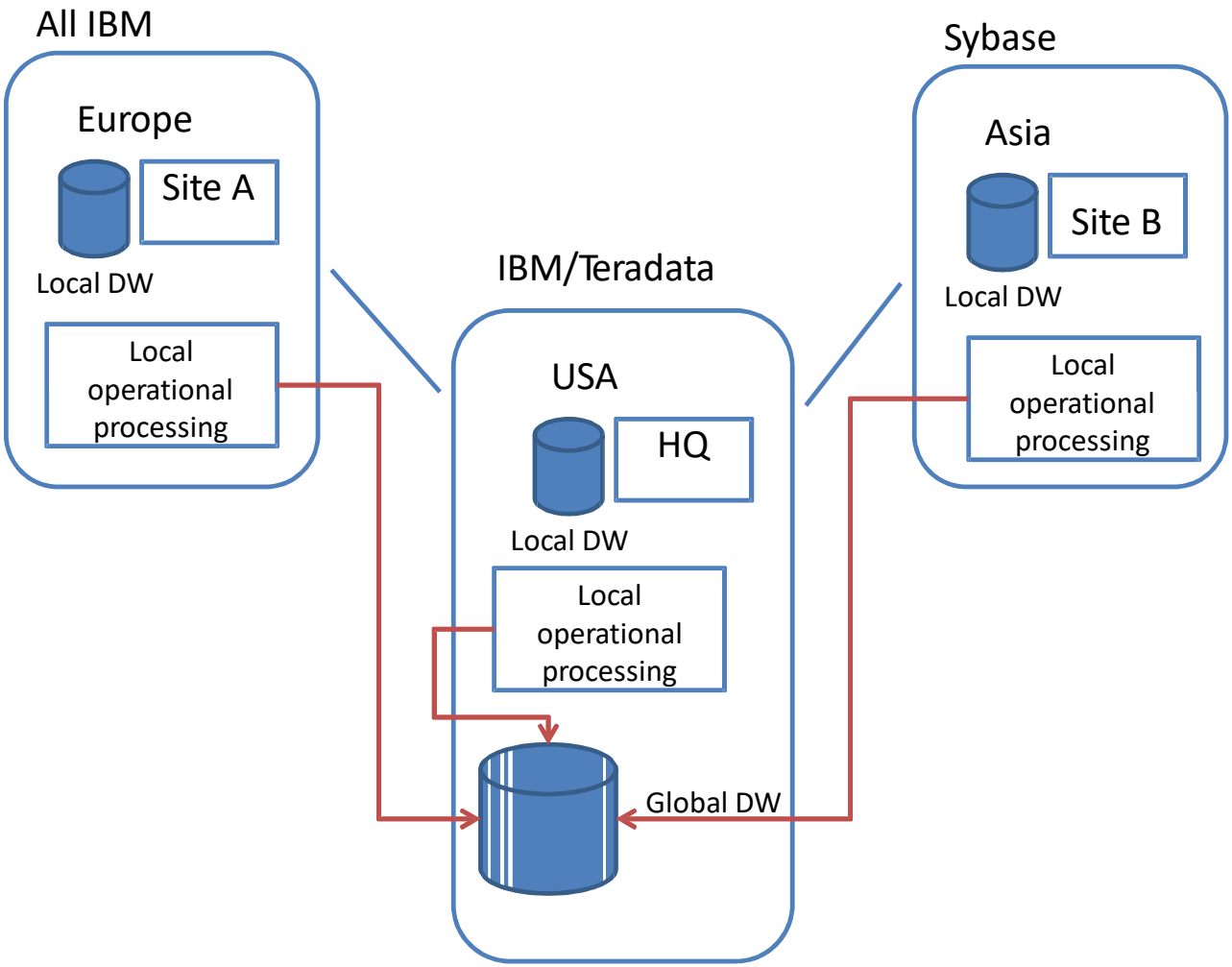
Distributed DW (cont'd.)



Distributed DW (cont'd.)

- **Technologically** distributed DW
  - Placing the DW on the distributed technology of a vendor
  - Advantages
    - The entry cost is cheap – large centralized hardware is expensive
    - No theoretical limit to how much data can be placed in the DW – we can add new servers to the network

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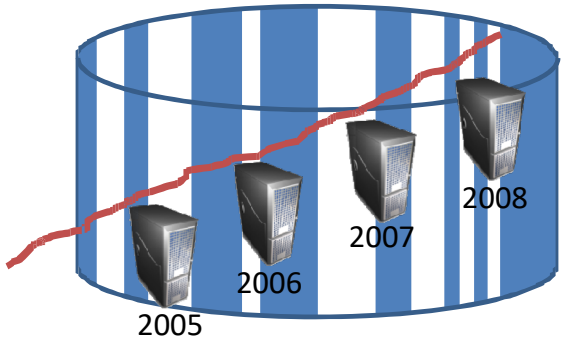
Distributed DW (cont'd.)

– As the DW starts to expand network data **communication** starts playing an important role

- Example: Let's simplify and consider we have 4 nodes holding each data regarding the last 4 years
- Now let's consider we have a query which needs to access the data from the last 4 years: such a query arises the issue of transporting large amount of data between processors



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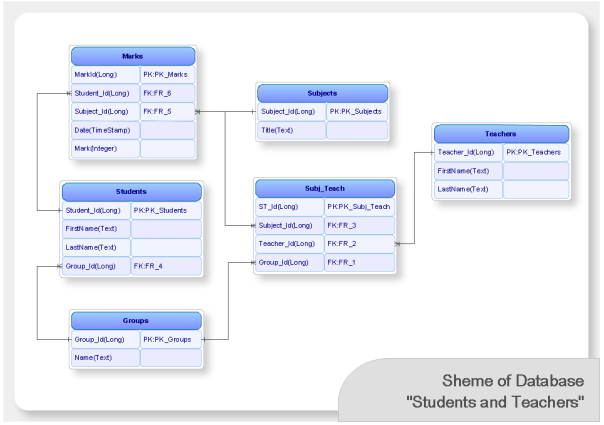
Data Modeling

- Data Modeling / DB Design - Basics
  - Is the process of creating a data model by analyzing the requirements needed to support the business processes of an organization
    - It is sometimes called database modeling/design because a data model is eventually implemented in a database



Data Modeling (cont'd.)

- **Data models**
  - Provide the **definition** and **format** of data
  - Graphical representations of the data within a specific area of interest
    - Enterprise Data Model: represents the integrated data requirements of a complete business organization
    - Subject Area Data Model: Represents the data requirements of a single business area or application

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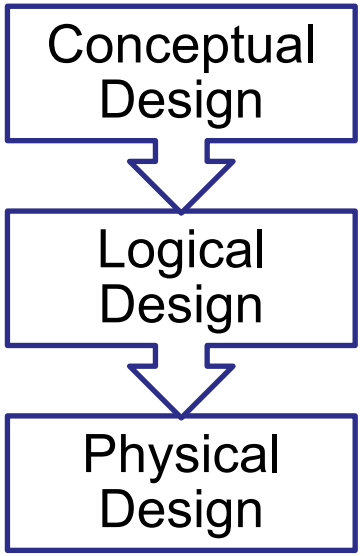
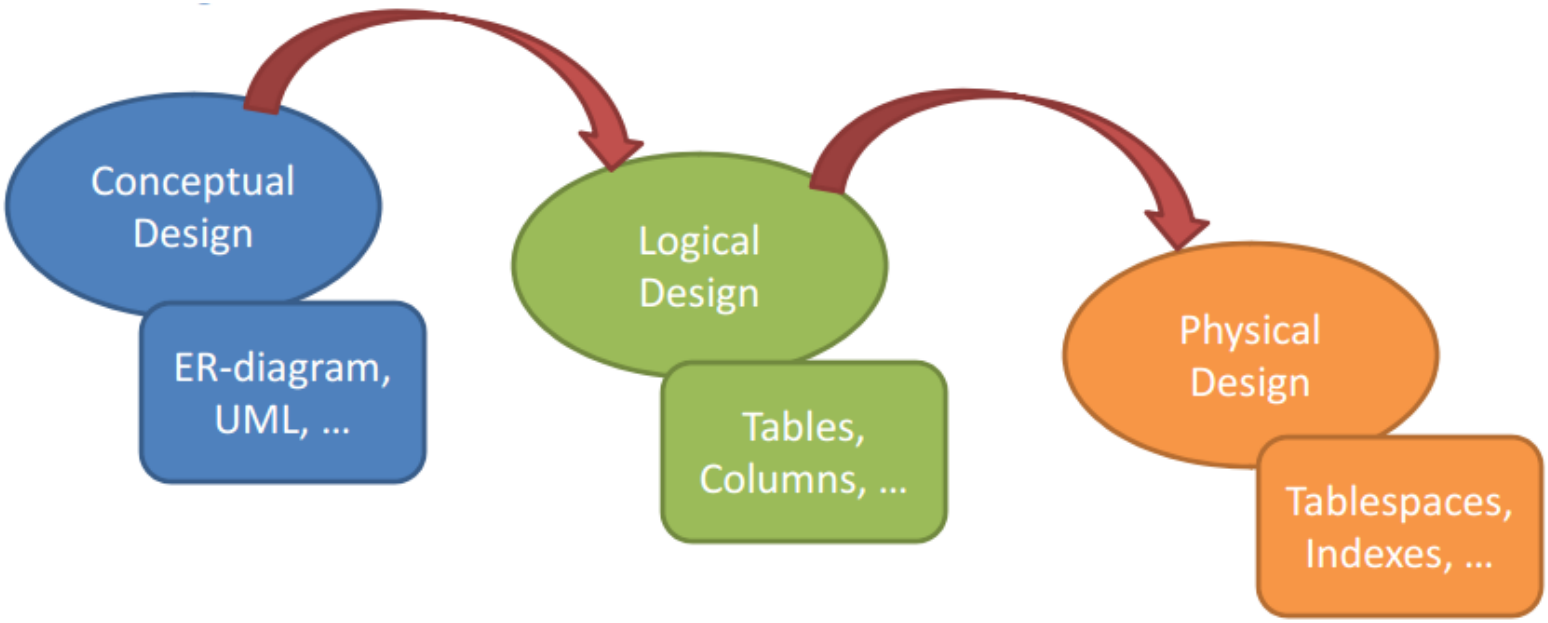
Data Modeling (cont'd.)

- Conceptual Design
  - Transforms data requirements to conceptual model
  - Conceptual model describes data entities, relationships, constraints, etc. on high-level
    - Does not contain any implementation details
    - Independent of used software and hardware
- Logical Design (next lecture)
  - Maps the conceptual data model to the logical data model used by the DBMS
    - e.g. relational model, dimensional model, …
    - Technology independent conceptual model is adapted to the used DBMS software
- Physical Design (2nd next lecture)
  - Creates internal structures needed to efficiently store/manage data
    - Table spaces, indexes, access paths, …
    - Depends on used hardware and DBMS software



Data Modeling (cont'd.)

- Going from one phase to the next:
  - The phase must be complete
    - The result serves as input for the next phase
  - Often automatic transition is possible with additional designer feedback



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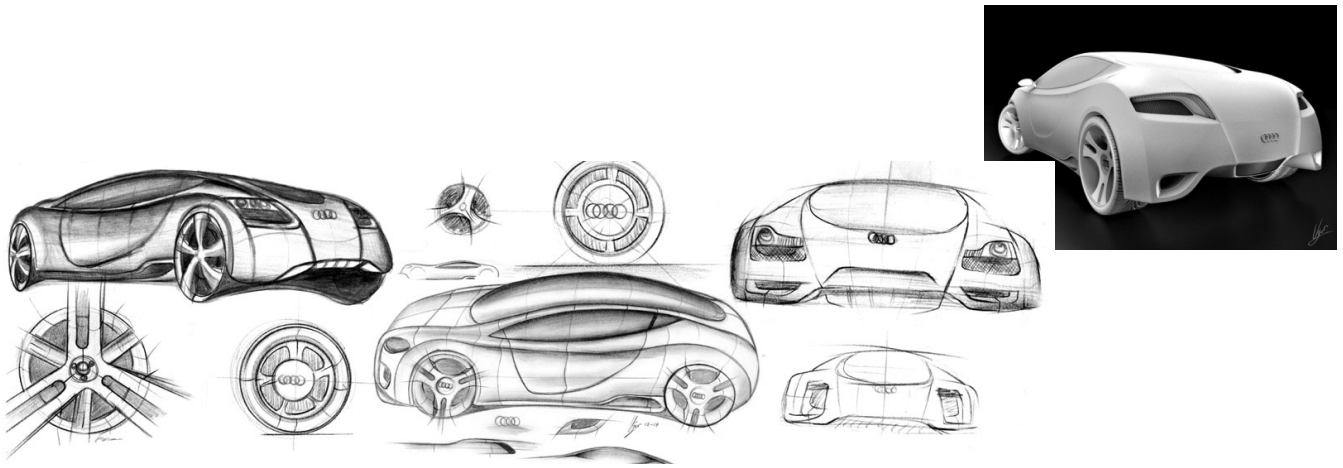
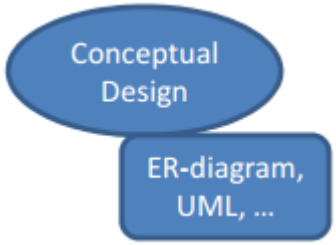
Conceptual Model

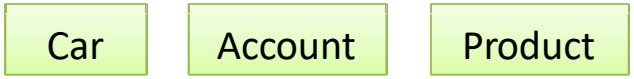
- Highest conceptual grouping of ideas
  - Data tends to naturally cluster with data from the same or similar categories relevant to the organization
- The major relationships between subjects have been defined
  - Least amount of detail



Conceptual Model (cont'd.)

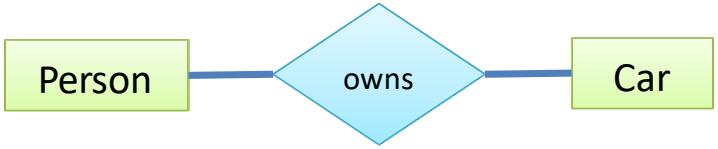


- Conceptual design
  - Entity-Relationship (ER) Modeling
    - Entities - "things" in the real world
      - E.g. Car, Account, Product



    - Attributes – property of an entity, entity type, or relationship type

      - E.g. color of a car, balance of an account, price of a product
    - Relationships – between entities there can be relationships, which also can have attributes
      - E.g. Person owns Car



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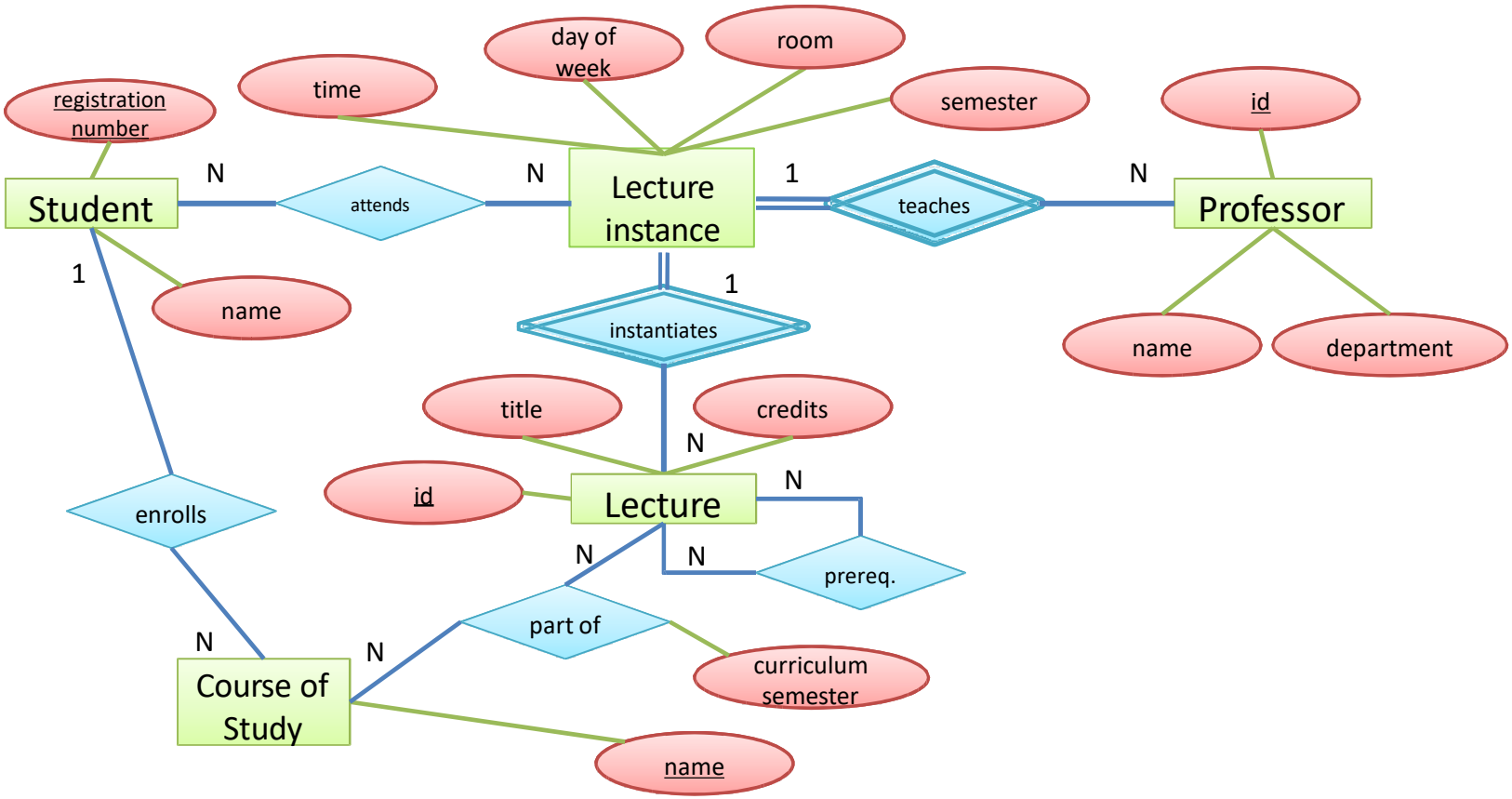
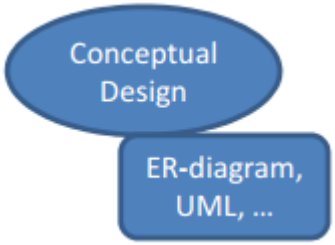
Conceptual Model (cont'd.)



Conceptual Model (cont'd.)

- Conceptual design in usually done using the Unified Modeling Language (UML)
  - Class Diagram, Component Diagram, Object Diagram, Package Diagram…
  - For Data Modeling only Class Diagrams are used
    - Entity type becomes class
    - Relationships become associations
    - There are special types of associations like: aggregation, composition, or generalization



CLASS NAME
attribute 1 : domain … attribute n : domain
operation 1 … operation m

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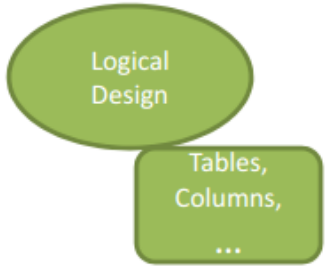
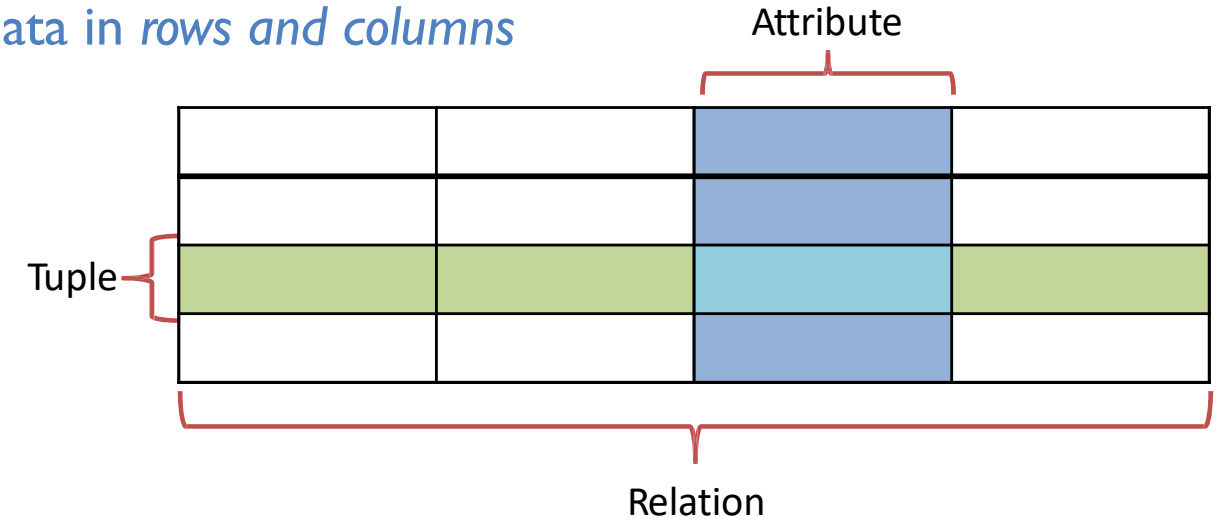
Logical Model

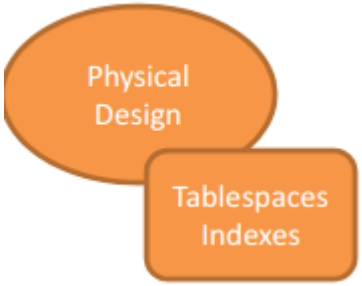


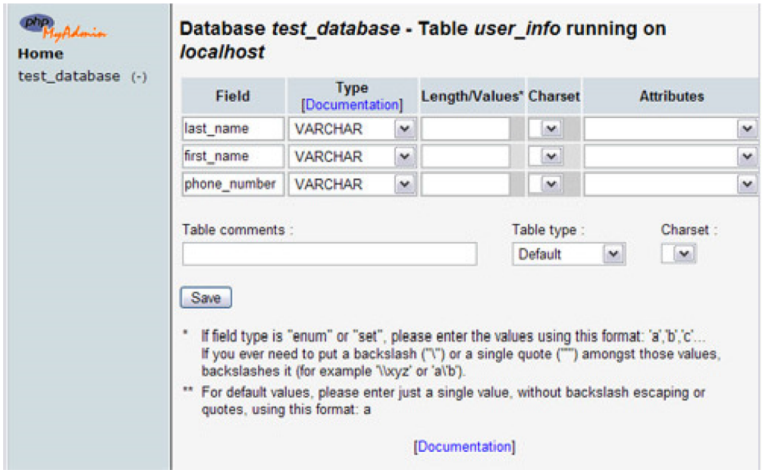
- Logical design arranges data into a logical structure
  - Which can be mapped into the storage objects supported by DBMS
    - In the case of RDB, the storage objects are *tables* which store data in *rows and columns*



Physical Model

- Physical design specifies the physical configuration of the database on the storage media
  - Detailed specification of: data elements, data types, indexing options, and other parameters residing in the DBMS data dictionary





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Data Model in DW

- Managing Complex Data Relationships
  - Helps keep track of the complex environment that is a DW
    - Many complex relationships exist, with the ability to change over time
  - Transformations and integration from various systems of record need to be worked out and maintained
  - Provides the means of supplying users with a **roadmap** through the data and relationships

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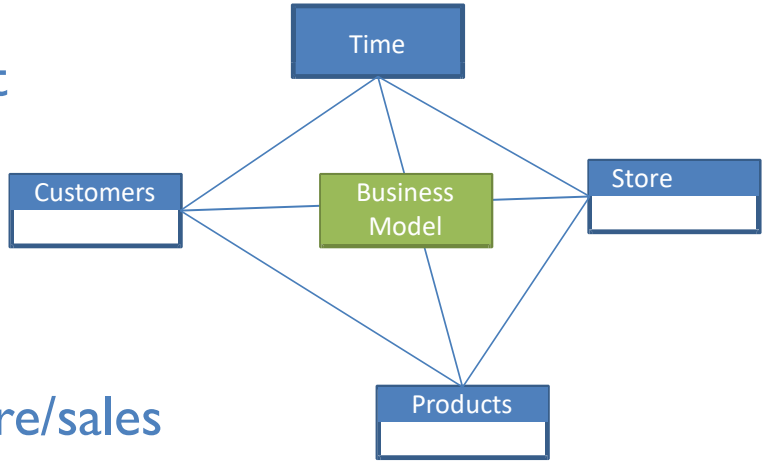
Conceptual Model in DW

- Modeling business queries
  - Goal
    - Define the purpose, and decide on the subject(s) for the data warehouse

      Identify questions of interest
  - Subject
    - Who bought the products? (customers structure)
    - Who sold the product? (store/sales organization structure)
    - What was sold? (product structure)
    - When was it sold? (time structure)



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Conceptual Model in DW (cont'd.)

- For **Conceptual design** in DW conventional techniques like E/R or UML are not appropriate
  - Lack of necessary semantics for modeling the multidimensional data model
  - E/R are constituted to
    - Remove redundancy in the data model
    - Facilitate retrieval of individual records
  - Therefore optimize OLTP
  - In the case of DW, however redundancy and MaterializedViews help speed up Analytical queries

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Conceptual Model in DW (cont'd.)

- Components
  - **Facts:** a fact is a focus of interest for decision-making, e.g., sales, shipments..
  - **Measures:** attributes that describe facts from different points of view, e.g., each sale is measured by its revenue
  - **Dimensions:** discrete attributes which determine the granularity adopted to represent facts, e.g., product, store, date
  - **Hierarchies:** are made up of dimension attributes
    - Determine how facts may be aggregated and selected, e.g., day – month – quarter - year

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Conceptual Model in DW (cont'd.)

- Conceptual design models for DW
  - Multidimensional Entity Relationship (ME/R) Model
  - Multidimensional UML (mUML)
  - Other methods e.g., Dimension Fact Model, Totok approach, etc.

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Multidimensional ER Model

- ME/R Model
  - Its purpose is to create an **intuitive representation** of the multidimensional data that is optimized for high-performance access
  - It represents a specialization and evolution of the E/R to allow specification of **multidimensional semantics**

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Multidimensional ER Model (cont'd.)

- ME/R notation was influenced by the following considerations
  - Specialization of the E/R model
    - All new elements of the ME/R have to be specializations of the E/R elements
    - In this way the flexibility and power of expression of the E/R models are not reduced
  - Minimal expansion of the E/R model
    - Easy to understand/learn/use: the number of **additional elements** should be small
  - Representation of the multidimensional semantics
    - Although being minimal, it should be powerful enough to be able to represent multidimensional semantics

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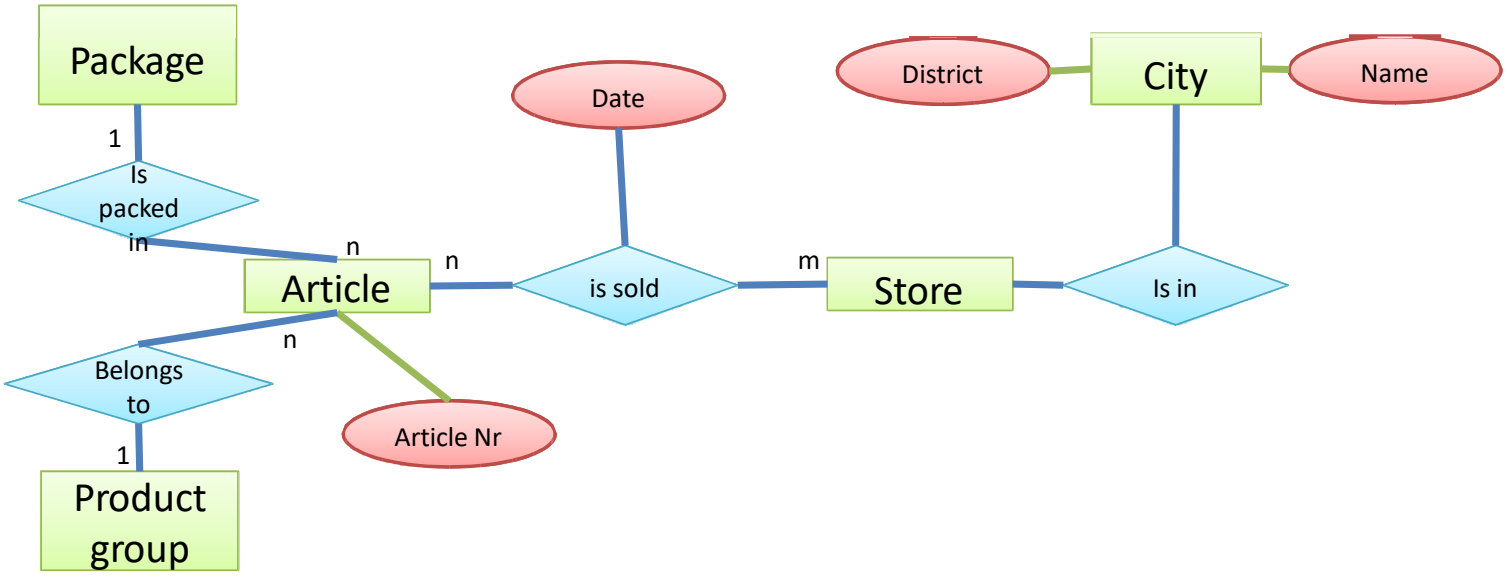
Multidimensional ER Model (cont'd.)

- There are 3 main ME/R constructs
  - The **fact node**
  - The **level node**
  - A special **binary classification edge**

Multidimensional ER Model (cont'd.)

- Lets consider a **store scenario** designed in E/R
  - Entities bear little semantics
  - E/R doesn't support classification and aggregation levels



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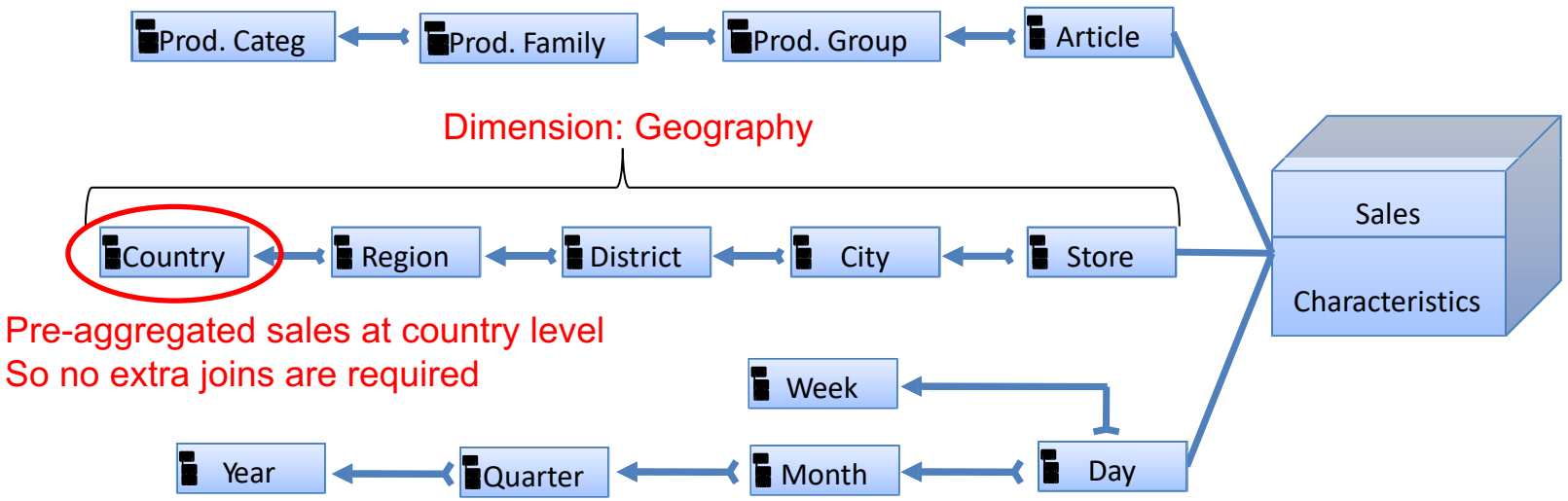
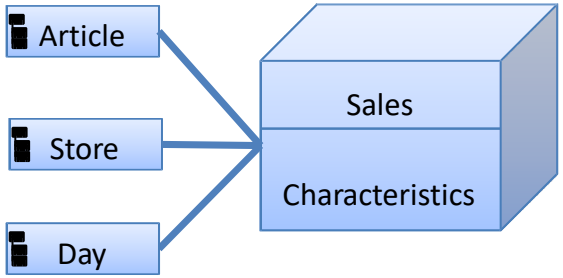
Multidimensional ER Model (cont'd.)

- **ME/R** notation:

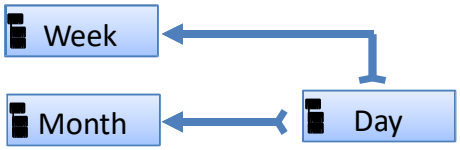


Multidimensional ER Model (cont'd.)

- ME/R notation:
  - Sales was elected as **fact node**
  - The dimensions are **product, geographical area and time**
  - The dimensions are represented through the so called **Basic Classification Level**



  - Alternative paths in the classification level are also possible



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Summary

- Tier Architecture
- Distributed DW
- DW Data Modeling

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Summary (cont'd.)

- DW are usually distributed geographically and technologically
- Data Modeling – Conceptual Modeling
  - In conceptual modeling for DW, conventional techniques like E/R or UML are not appropriate
  - Appropriate methods are:
    - Multidimensional Entity Relationship (ME/R) Model
    - Multidimensional UML (mUML)

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Next Lecture

- Data Modeling (continued)
  - Logical model
    - Cubes, Dimensions, Hierarchies, Classification Levels