Business Intelligence

Conceptual Data Warehouse Design

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Business Intelligence

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MultiDim: A Conceptual Model for Data Warehouses

Conceptual Multidimensional Models

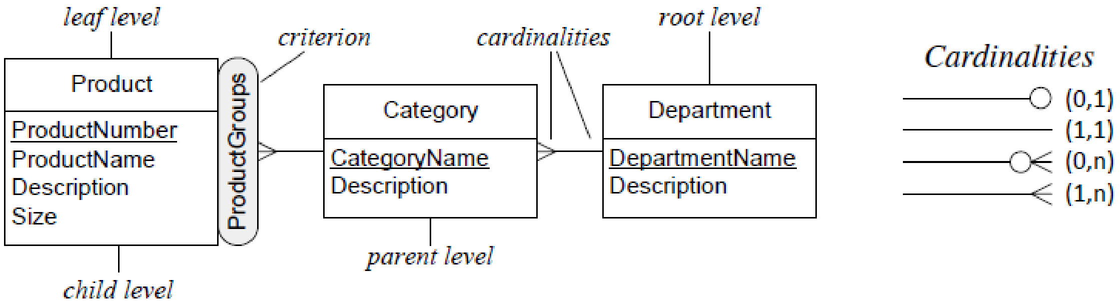
- **Conceptual models**
  - Allow better communication between designers and users to understand application requirements
  - More stable than implementation-oriented (logical) schema, which changes with the platform
  - Provide better support for visual user interfaces
- No well-established conceptual model for multidimensional data
- Several proposals based on UML, on the ER model, or using specific notations
- Problems:
  - Cannot express complex kinds of hierarchies
  - Lack of a mapping to the implementation platform
- Currently, data warehouses are designed using mostly logical models (star and snowflake schemas)
  - Difficult to express requirements (technical knowledge required)
  - Limit users to defining only elements that the underlying implementation systems can manage
  - Example: Users constrained to use only the simple hierarchies supported in current tools

MultiDim: A Conceptual Multidimensional Model

- Based on the entity-relationship model
- Includes concepts like:
  - dimensions
  - hierarchies
  - facts
  - measures
- Supports various kinds of hierarchies existing in real-world applications
- Can be mapped to star or snowflake relational structures

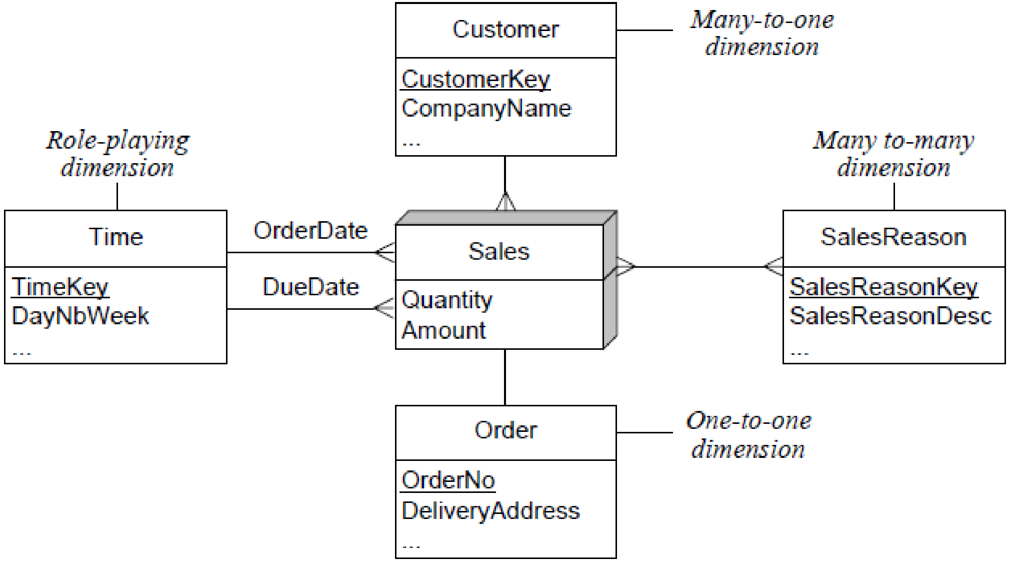
MultiDim Model: Notation

- Dimension: level or one or more hierarchies
  - Hierarchy: several related levels
  - Level: entity type
  - Member: every instance of a level
  - Child and parent levels: the lower and higher levels
  - Leaf and root levels: first and last levels in a hierarchy
  - Cardinality: Minimum/maximum numbers of members in a level related to members in another level
  - Criterion: Expresses different hierarchical structures used for analysis
  - Key attribute: Indicates how child members are grouped
  - Descriptive attributes: Describe characteristics of members

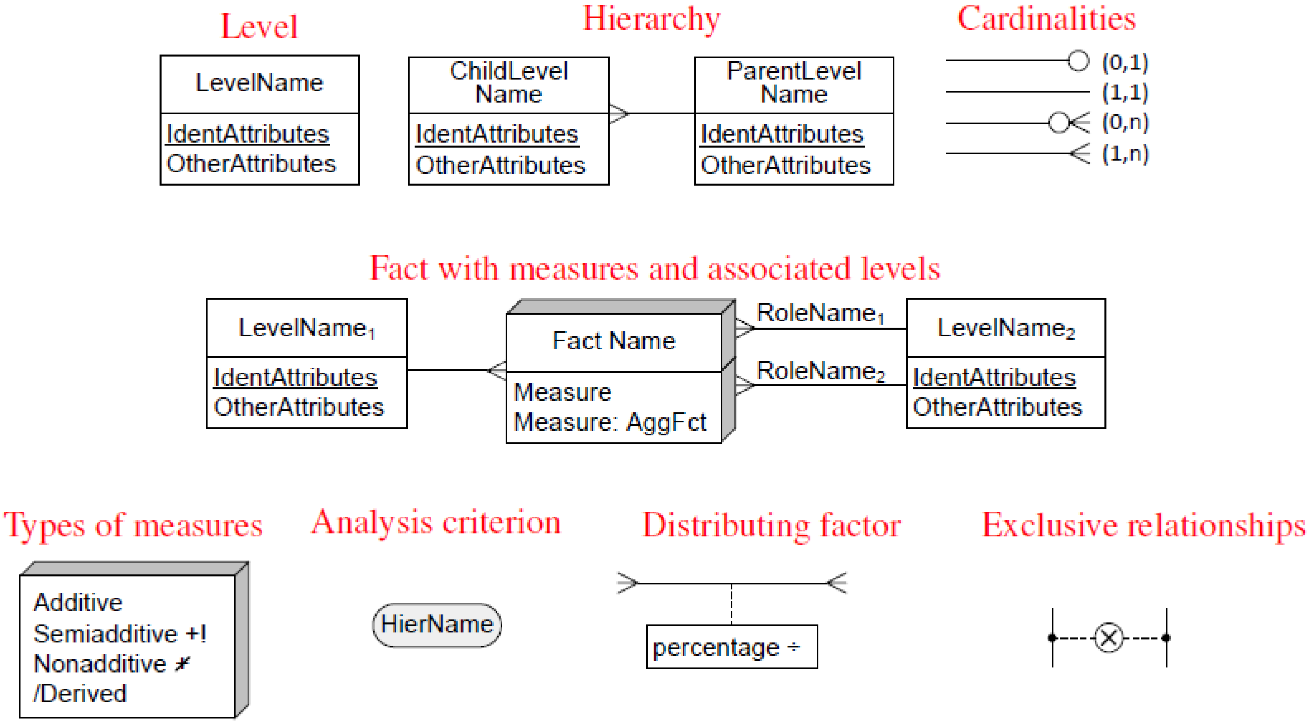


MultiDim Model: Notation

- **Fact**: Relates measures to leaf levels in dimensions
  - Dimensions can be related to fact with one-to-one, one-to-many, or many-to-many
  - Dimension can be related several times to a fact with different roles



MultiDim Model: Notation (summary)



Level

LevelName

IdentAttributes

OtherAttributes

Hierarchy

ChildLevel Name

IdentAttributes

OtherAttributes

ParentLevel Name

IdentAttributes

OtherAttributes

Cardinalities

(0,1)

(1,1)

(0,n)

(1,n)

Fact with measures and associated levels

LevelName$_1$

IdentAttributes

OtherAttributes

Fact Name

Measure

Measure: AggFct

RoleName$_1$

RoleName$_2$

LevelName$_2$

IdentAttributes

OtherAttributes

Types of measures

Additive

Semiadditive +!

Nonadditive $\not+$

/Derived

Analysis criterion

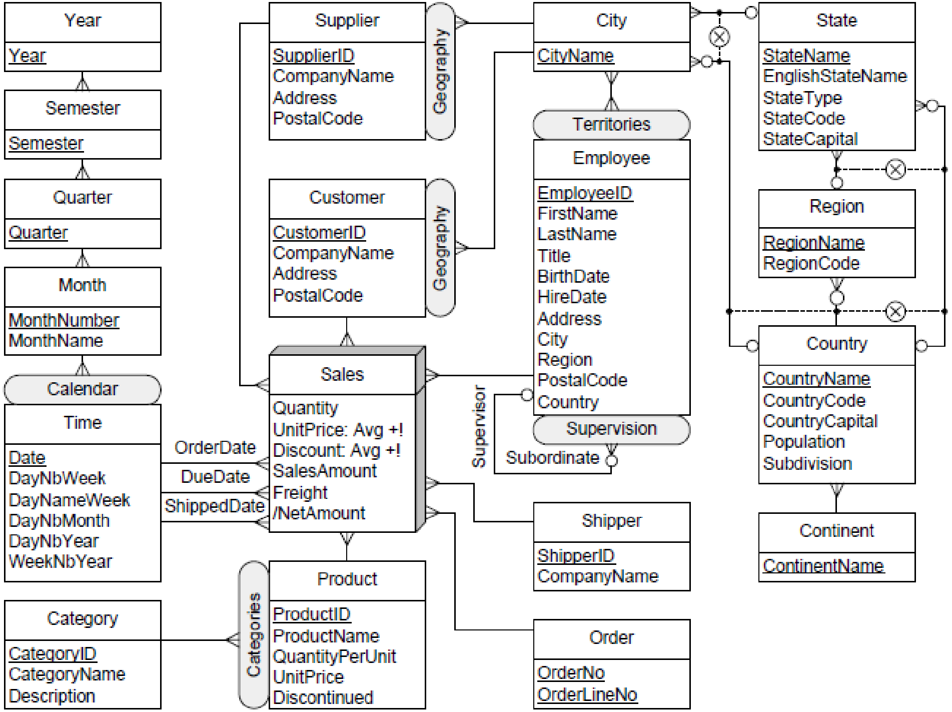
HierName

Distributing factor

percentage ÷

Exclusive relationships

MultiDim Conceptual Schema of the Northwind Data Warehouse



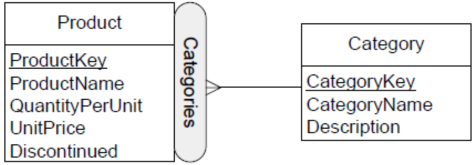
Dimension Hierarchies

Dimension Hierarchies

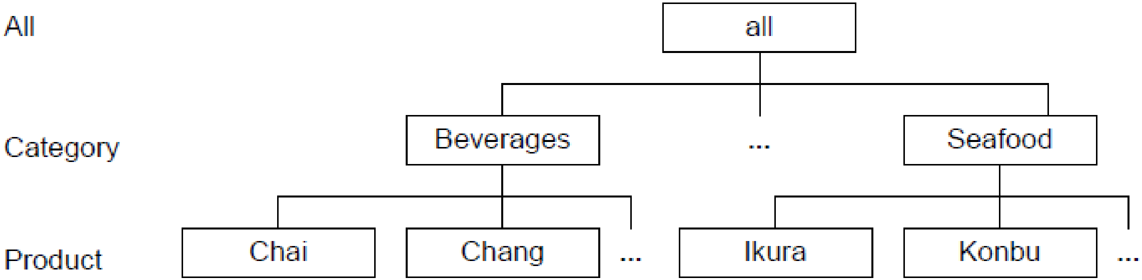
- **Crucial in analytical applications**
- **Enable analysis at various abstraction levels**
- **In real-world situations, users must deal with complex hierarchies of various kinds**
- **Logical models of current DW and OLAP systems allow only a limited set of kinds of hierarchies**
    - **Users unable to capture the essential semantics of multidimensional applications**
    - **They must limit their analysis to the predefined set of hierarchies supported by the tools**
- **At the conceptual level, focus is to establish sequences of levels that should be traversed during roll-up and drill-down**
- **Distinction between the various kinds of hierarchies should also be made at the instance level**
- **Cardinalities in parent-child relationships must be considered**
- **MultiDim includes classification of hierarchies at the schema and instance level and proposes a graphical notation**

Balanced Hierarchies

- **At schema level: only one path where all parent-child relationships are many-to-one and mandatory**

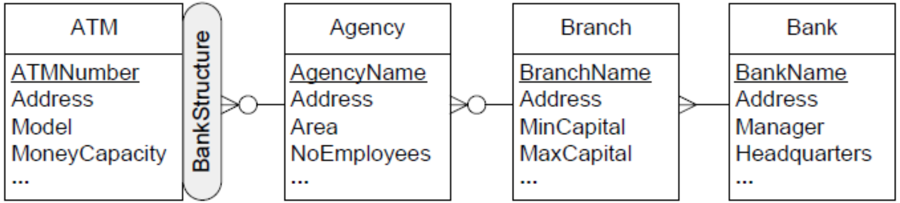


- **At instance level: members form a balanced tree (all the branches have the same length)**
- **All parent members have at least one child member, and a child belongs exactly to one parent**

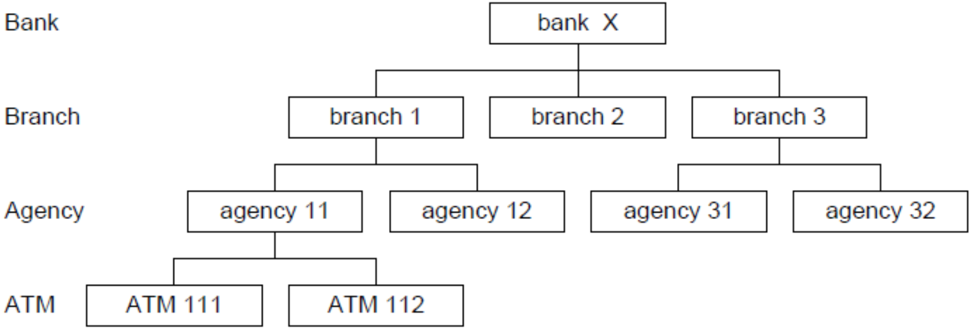


Unbalanced Hierarchies

- At schema level: one path where all parent-child relationships are many-to-one, but some are optional

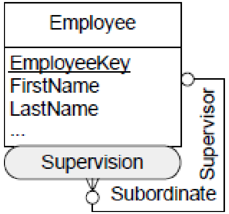


- At instance level: members form an unbalanced tree

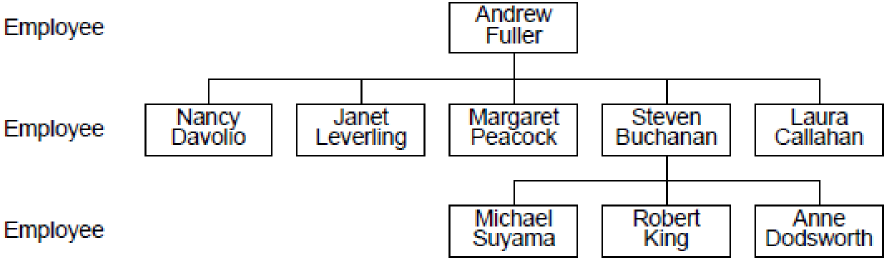


Recursive Hierarchies

- A special case of unbalanced hierarchies
- The **same level** is linked by the two roles of a parent-child relationship
- Used when all hierarchy levels express the same semantics
- The characteristics of the parent and child are similar (or the same)
- **Schema level**

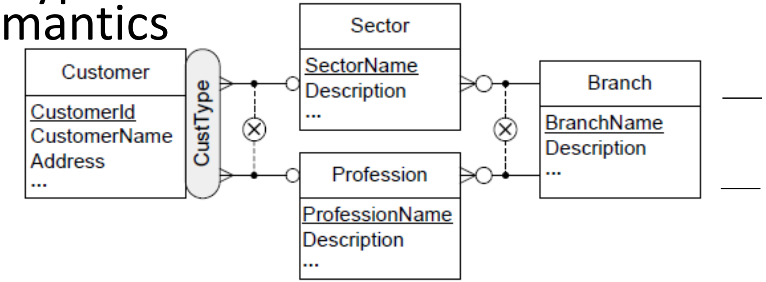


- **Instance level**

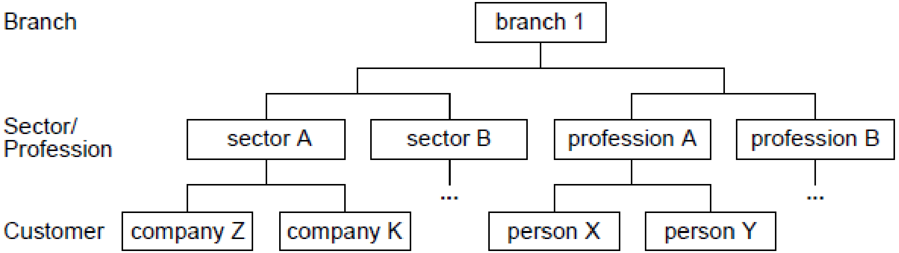


Generalized Hierarchies

- At **schema level**: multiple exclusive paths sharing at least the leaf level; may also share other levels
- Two aggregation paths, one for each type of customerUsed when all hierarchy levels express the same semantics



- At **instance level**: each member belongs to only one path

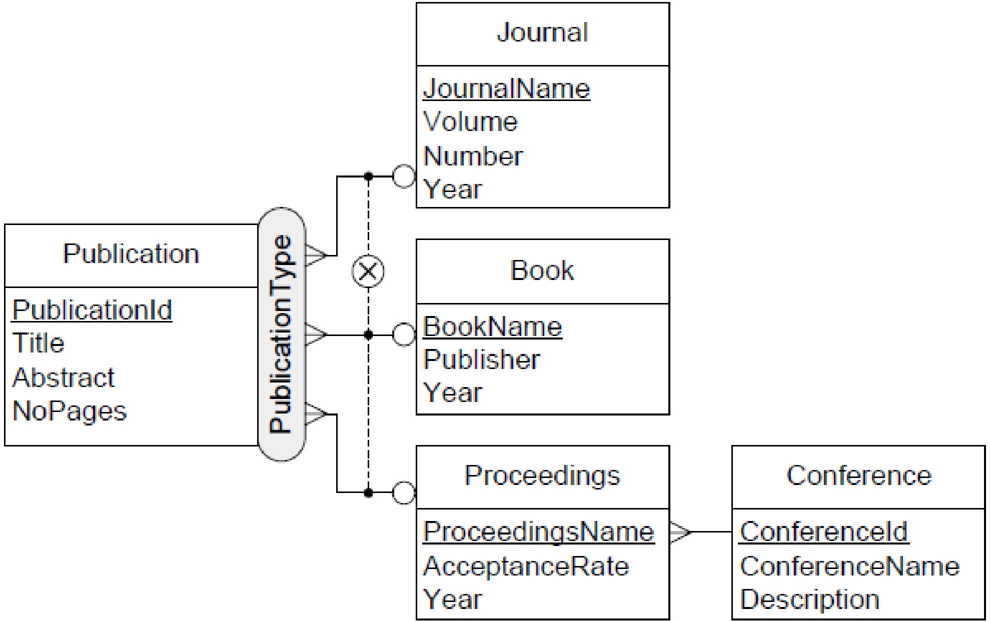


Generalized Hierarchies

- **Supertype** of the generalization/specialization relationship is used in generalized hierarchies for representing a **leaf level**
- It only includes those attributes that represent concepts at the lowest granularity
  - E.g., CustomerId, CustomerName, and Address
- This kind of hierarchy **does not satisfy the summarizability conditions**
  - The mapping from the splitting level to the parent levels is incomplete
    - E.g., not all customers roll up to the Sector level
    - E.g., not all customers are mapped to the Profession level
- Conventional aggregation mechanism should be modified when a splitting and joining levels are reached in a drill-down and roll-up operations
- Traditional approach can be used for aggregating measures for common hierarchy levels

Generalized Hierarchies

- In generalized hierarchies, it is not necessary that splitting levels must be joined

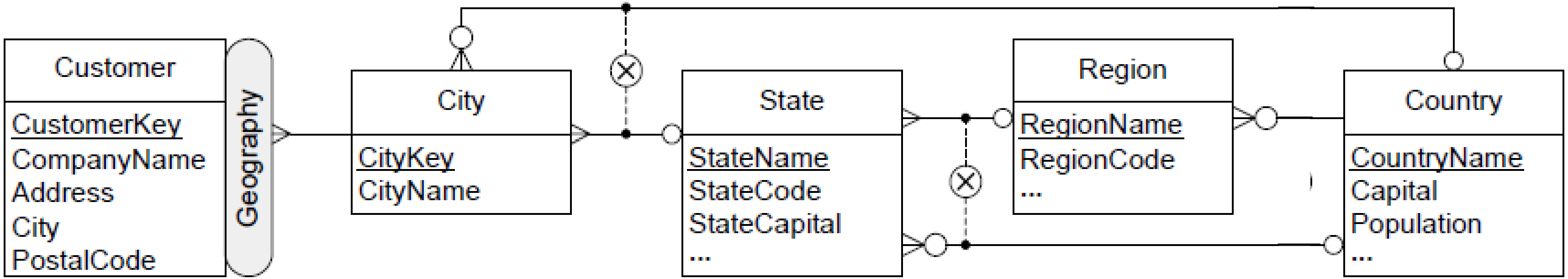


Generalized Hierarchies

- Not all generalization/specialization hierarchies can be represented
- **Partial specializations**: Induce an additional path in the generalized hierarchy, relating the common levels
- **Overlapping specializations**: Various options are possible according to the users' requirements and the availability of measures
  - Example: An overlapping generalization where a person who owns a company buys products either for his/her individual use or for the company
  - If measures are known only for the superclass Customer, only the hierarchy with common levels will be represented, e.g., the Customer and Area levels
  - If measures are known only for each subclass, e.g., for Person and Company:
    - Separate dimensions and fact relationships with corresponding measures can be created for each specialization → difficult to manage dimensions with overlapping sets of members
    - Another solution: Disallow overlapping generalizations

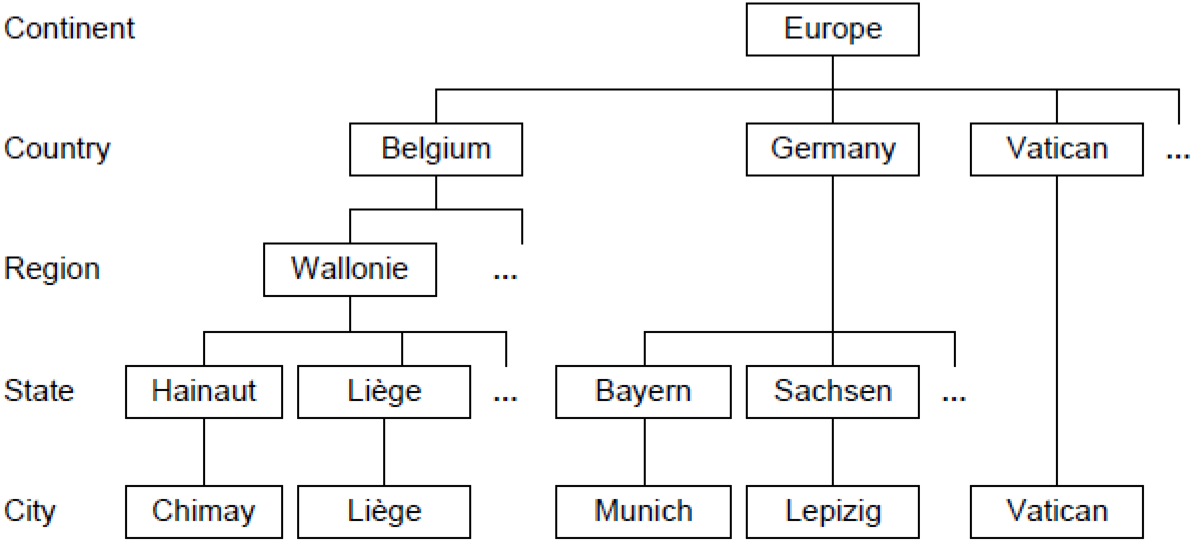
Generalized Hierarchies

- Also known as ragged or level-skipping hierarchies
- A special case of generalized hierarchies
- At the schema level: Alternative paths are obtained by skipping one or several intermediate levels



Generalized Hierarchies

- At **instance level**: Path length from the leaves to the same parent can be different for different members



Continent Europe

Country Belgium Germany Vatican ...

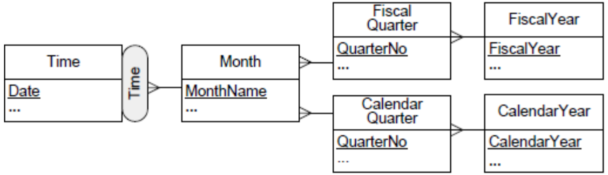
Region Wallonie ...

State Hainaut Liège ... Bayern Sachsen ...

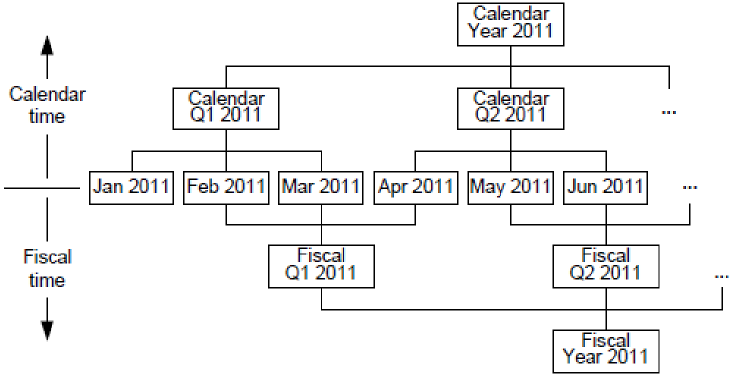
City Chimay Liège Munich Lepizig Vatican

Alternative Hierarchies

- At **schema level**: Multiple nonexclusive hierarchies that share at least the leaf level and account for the same analysis criterion



- At **instance level**: Members form graph

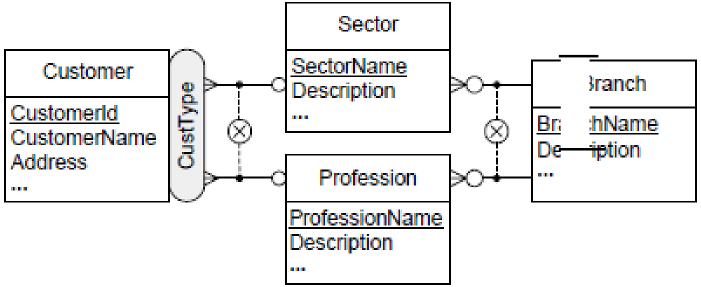


Alternative Hierarchies

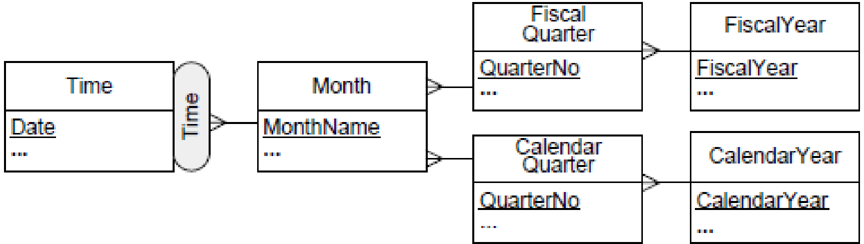
- Needed to analyze measures from an unique perspective (e.g., time) using alternative paths
- Measures will participate totally in each component hierarchy => conventional aggregation procedures
- It is not semantically correct to simultaneously combine different component hierarchies
- Combination can give meaningless intersections, i.e., a combination of members that do not have values for aggregated measures, e.g., B1-2001 and Q2-2001
- Users must choose only one of the alternative paths for their analysis and switch to other one if required

Generalized vs. Alternative Hierarchies

- Both hierarchies
  - Share some levels
  - Use one analysis criterion

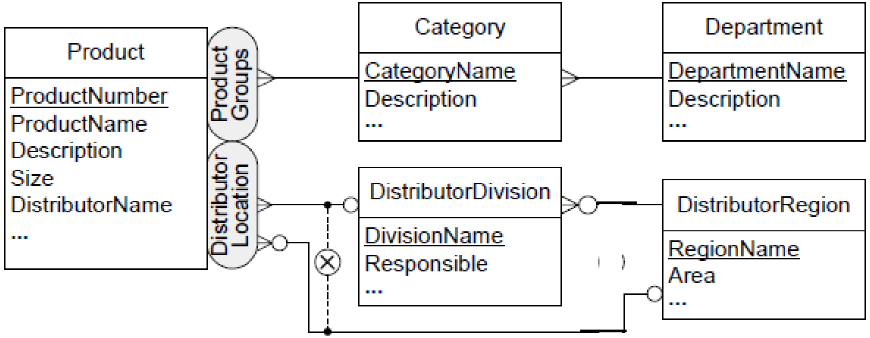


- A child member
  - Related to only one path in generalized hierarchies
  - Related to all paths in alternative hierarchies and users must choose one for analysis



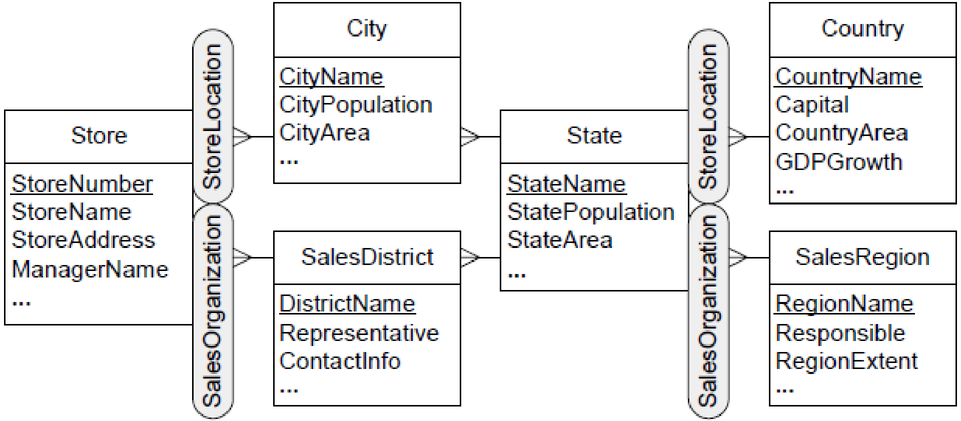
Parallel Hierarchies

- Dimension has associated **several hierarchies** accounting for **different analysis criteria**
- Two different types
  - Parallel **independent** hierarchies
  - Parallel **dependent** hierarchies
- Parallel **independent** hierarchies
  - Composed of disjoint hierarchies, i.e., hierarchies that **do not share levels**
  - Component hierarchies may be of different kinds



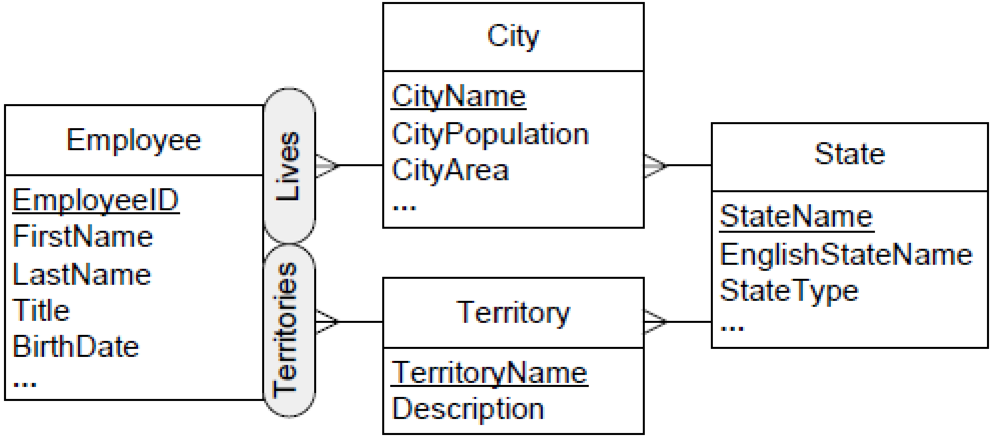
Parallel Hierarchies

- Parallel **dependent** hierarchies
- Composed of several hierarchies that account for different analysis criteria and share some levels
- Component hierarchies may be of different kinds



Parallel Hierarchies

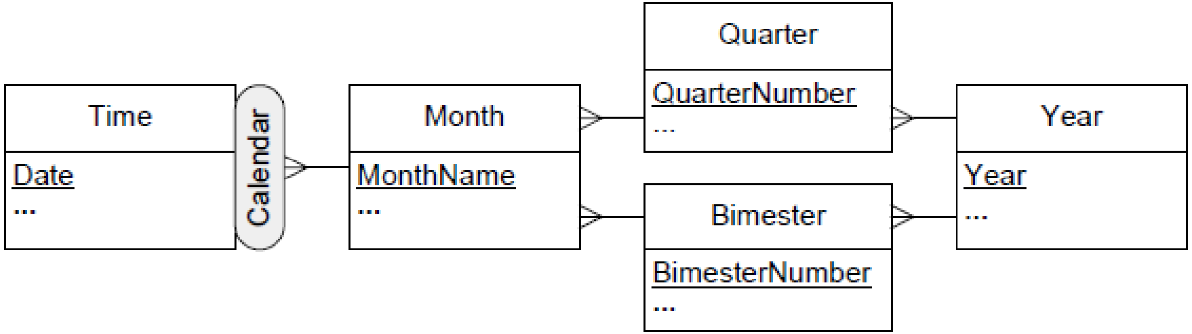
- Parallel dependent hierarchies leading to different parent members of the shared level



Alternative vs. Parallel Hierarchies

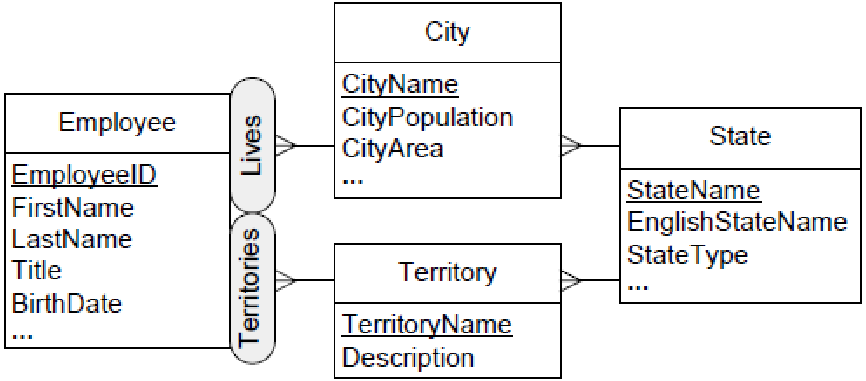
- Both hierarchies
  - Share some levels
  - May include several simple hierarchies
- Criterion
  - Only one for alternative hierarchies
  - Several for parallel hierarchies
- Combining hierarchies
  - Meaningless for alternative hierarchies
  - Useful for parallel hierarchies
- Reusing aggregated measures for common levels
  - Can be done for alternative hierarchies
  - Cannot be done for parallel hierarchies

Alternative vs. Parallel Hierarchies



- Aggregated measure for the Month level can be reused between both paths
- Traversing the Calendar hierarchy from a specific day in the Time level will end up in the same year independently of which path is used

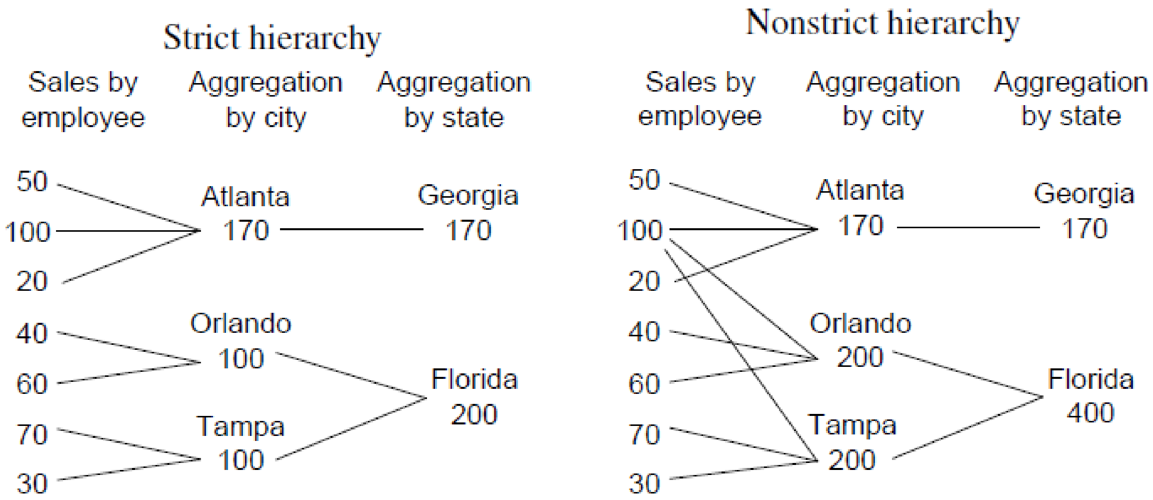
Alternative vs. Parallel Hierarchies



- Aggregated measure for State level cannot be reused between both paths
- Traversing the hierarchies Live and Work from the Employee to the State level will lead to different states for employees who live in one state and work in another

Nonstrict Hierarchies: Double Counting

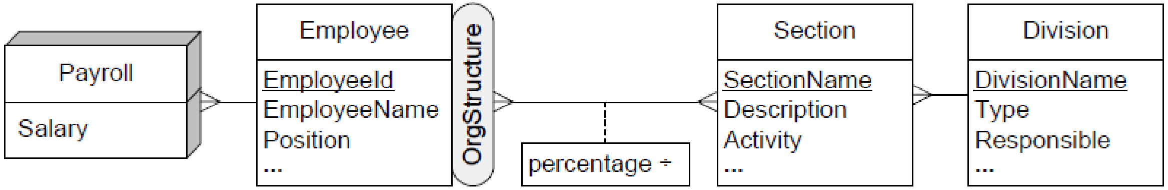
- Problem: **Double counting** of measures when a roll-up operation reaches a many-to-many relationship
- Examples of aggregation



Nonstrict Hierarchies: Solutions for Double Counting

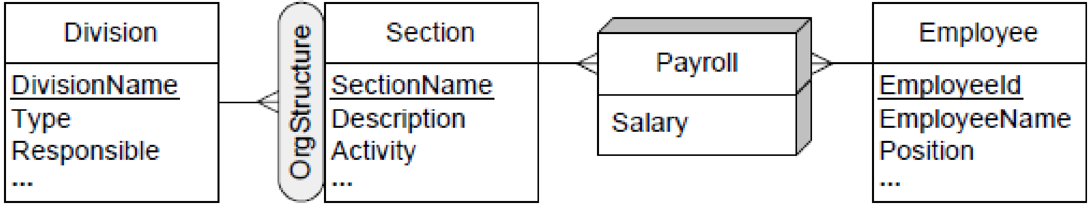
- Include a **distributing factor**
- Calculate **approximate** values of a distributing factor
- **Transform** a nonstrict hierarchy into a strict one:
  - **Create a new parent member** for each group of parent members linked to a single child member in a many-to-many relationship
  - **Choose one parent member as primary** and ignore the existence of other parent members
  - **Split the hierarchy in two** at the many-to-many relationship, where the levels from the parent level and beyond become a new dimension
- Each solution has its advantages and disadvantages and requires special aggregation procedures
- Appropriate solution must be chosen according to the situation at hand and user's requirements

Nonstrict Hierarchies: Distributing factor

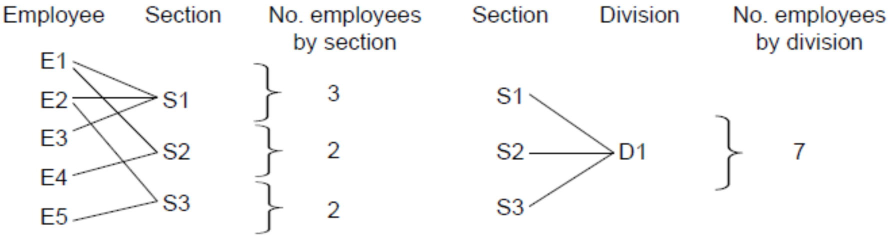


- Employees may work in several sections
- A measure represents an employee’s overall salary, i.e., the sum of the salaries paid in each section
- Distributing factor determines how measures are divided between several parent members
- Distributing factor is not always known
  - Percentage of time that an employee works in a section must be added to schema
- Sometimes this distribution is impossible to specify
  - E.g., participation of customer in joint account
- Distributing factor can be approximated by considering the total number of parent members with which the child member is associated
  - If an employee works in three sections, 1/3 of the value of the measure aggregated for each one

Nonstrict Hierarchies: Splitting the Hierarchy

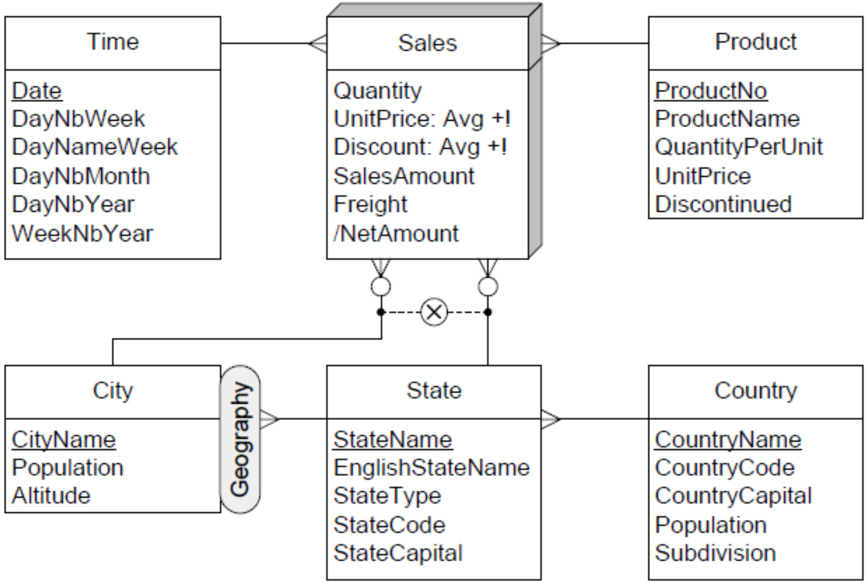


- Transform a nonstrict hierarchy into a strict one with an **additional dimension**
- **Focus of analysis** has changed from employee's salaries to employee's salaries by section
- Can only be applied when the **measure distribution is known**
- Nevertheless, double counting problem still remains
- Example: calculate the number of employees by section or by division



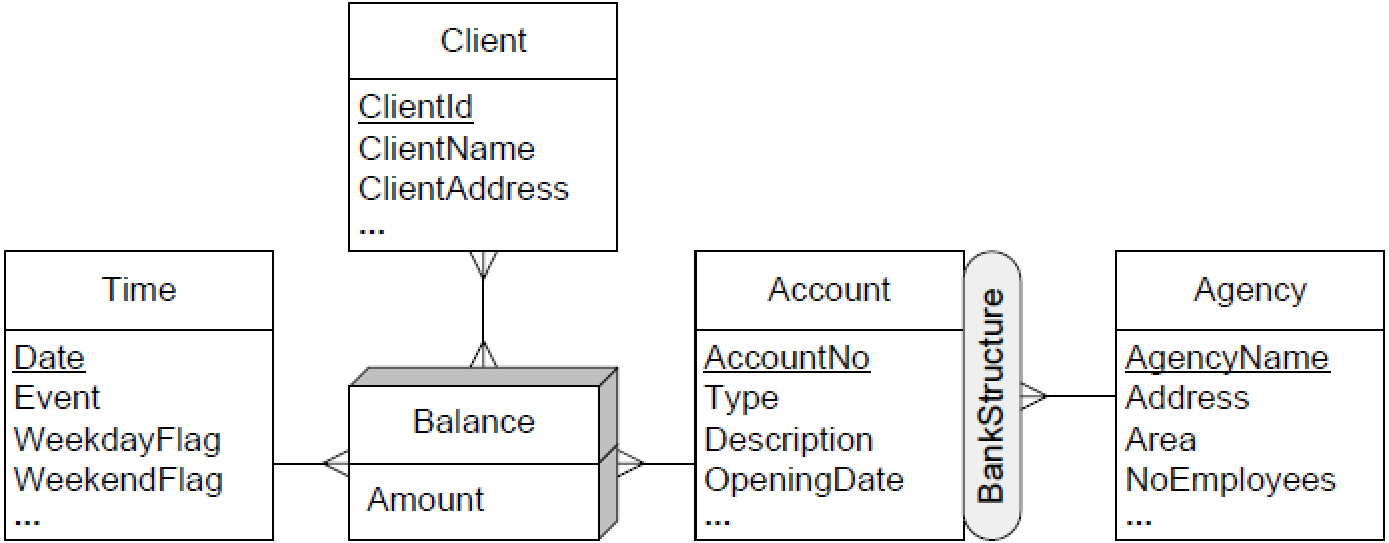
Advanced Modeling Aspects

Advanced Modeling Aspects: Facts with Multiple Granularities



- Sales captured at the city level or at the state level

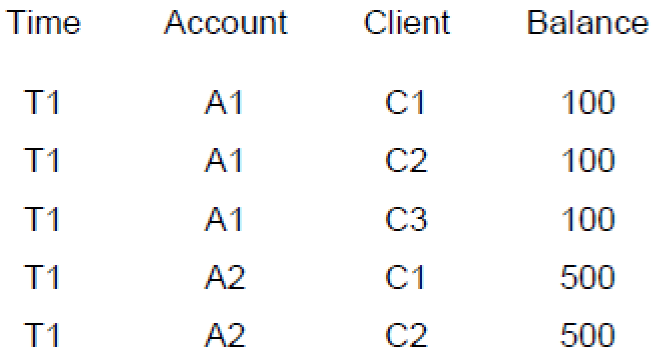
Advanced Modeling Aspects: Many-to-Many Dimensions



- Multidimensional schema for the analysis of bank accounts

Advanced Modeling Aspects: Many-to-Many Dimensions

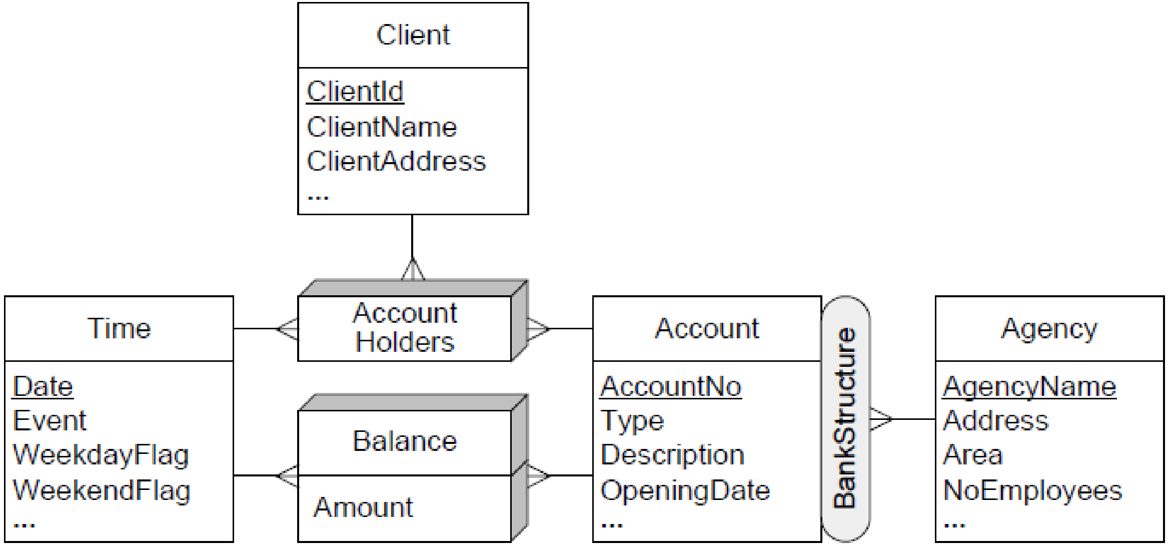
- Example of double-counting problem



Time	Account	Client	Balance
T1	A1	C1	100
T1	A1	C2	100
T1	A1	C3	100
T1	A2	C1	500
T1	A2	C2	500

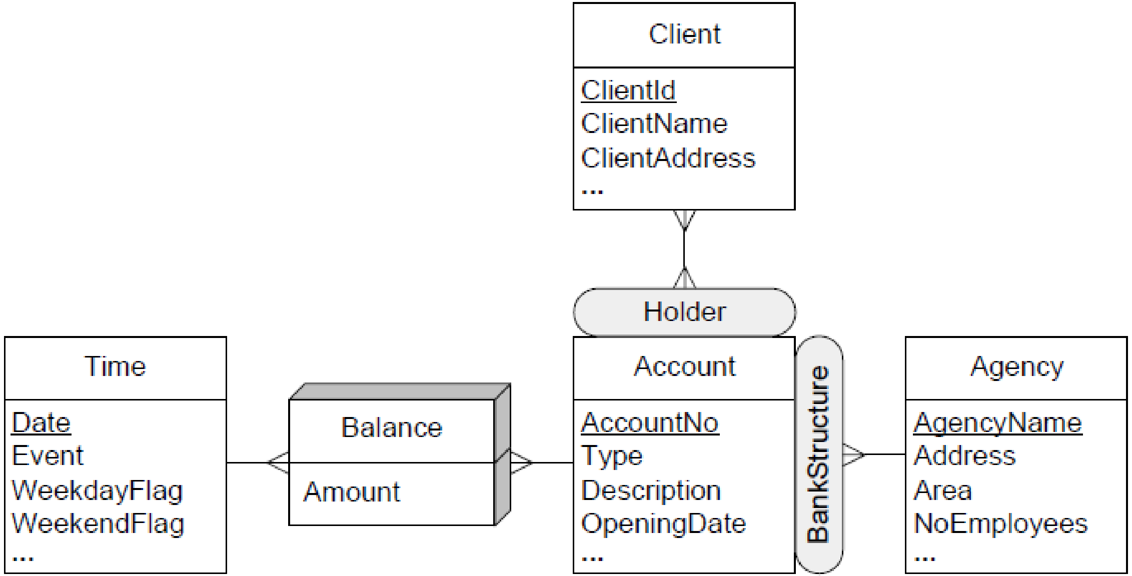
Advanced Modeling Aspects: Many-to-Many Dimensions

- Two possible decompositions of the fact
- (1) Creating two facts



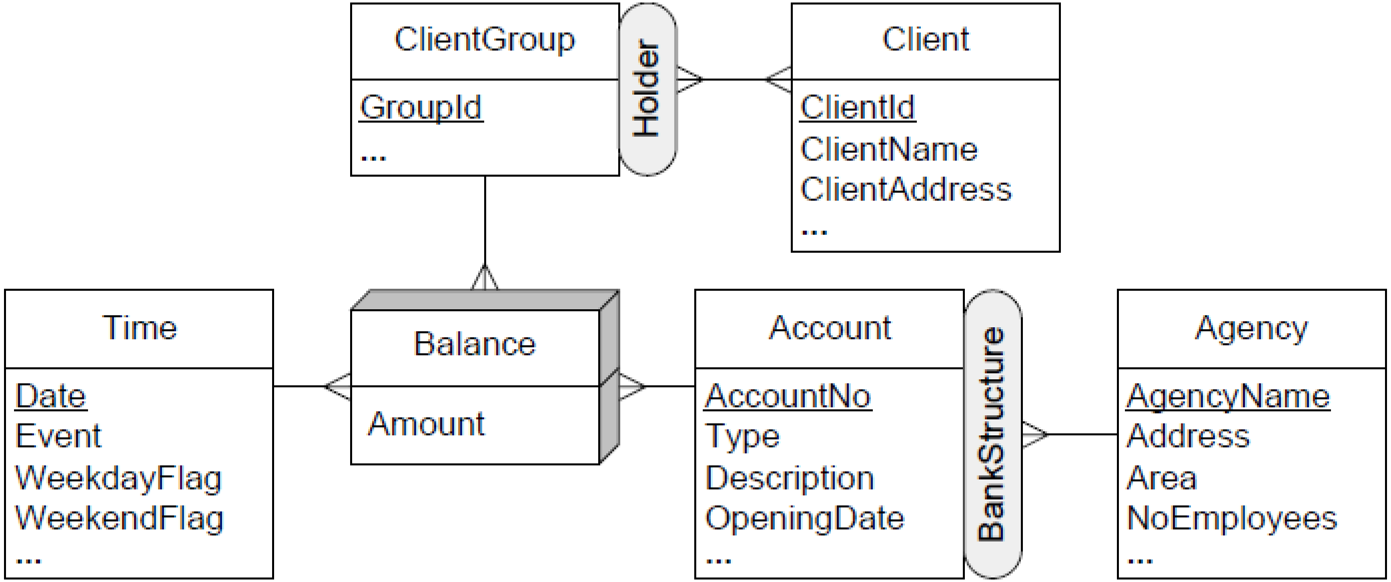
Advanced Modeling Aspects: Many-to-Many Dimensions

- Two possible decompositions of the fact
- (2) Including a nonstrict hierarchy



Advanced Modeling Aspects: Many-to-Many Dimensions

- Alternative decomposition of the schema



Exercises

Exercises

1. A data warehouse of a telephone provider consists of five dimensions, namely, caller customer, callee customer, time, call type, and call program, and three measures, namely, number of calls, duration, and amount.

- Design a MultiDim schema for the given problem.

Exercises

2. A data warehouse of a train company contains information about train segments. It consists of six dimensions, namely, departure station, arrival station, trip, train, arrival time, and departure time, and three measures, namely, number of passengers, duration, and number of kilometers.

- Design a MultiDim schema for the given problem.

Exercises

3. Consider the data warehouse of a university that contains information about teaching and research activities. On the one hand, the information about teaching activities is related to dimensions department, professor, course, and time, the latter at a granularity of academic semester. Measures for teaching activities are number of hours and number of credits. On the other hand, the information about research activities is related to dimensions professor, funding agency, project, and time, the latter twice for the start date and the end date, both at a granularity of day. In this case, professors are related to the department to which they are affiliated. Measures for research activities are the number of person months and amount.

- Design a MultiDim schema for the given problem.