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Outline

1. User Requirement Analysis

2. Dimensional Fact Model

3. Conceptual Design
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1. User Requirement Analysis
2. Dimensional Fact Model
3. Conceptual Design
Goal of User Requirements Analysis

- We skip the analysis and reconciliation of data sources, which should be the first step
- Instead, we start with the user requirement analysis
- Aims to collect end user needs for DW applications and usage
- Main “source” of information are the so-called business users (end users)
- Has strategic importance as it influences almost every decision made during the project
- Plays an essential role for the conceptual design (which is the next step)
- Different ways to elicit user requirements, e.g.,
  - Interviews
  - Glossary-based requirements analysis
Interviews

- Frequently used method are interviews with single users or small groups of users.
- Different types of questions
  - Open-ended questions
    - What do you think of data source quality?
    - What are the key objectives your unit has to face?
  - Closed questions
    - Are you interested in sorting out purchases by hour?
    - Do you want to receive a sales report every week?
  - Evidential questions
    - Could you please give me an example of how you calculate your business unit budget?
    - Could you please describe the issues with poor data quality that your business unit is experiencing?
Glossary-based Requirements Analysis

- Aims at creating tables that collect information about facts, dimensions, attributes and their relationship
- It is recommended that this analysis is focused on facts
- Facts are the concepts on which end users base decision-making processes
- Each fact describes a category of events taking place in enterprises
- Facts essentially represent business processes
- Frequently, this analysis is going hand-in-hand with the conceptual design
# Typical Facts of Different Application Fields

<table>
<thead>
<tr>
<th>Application field</th>
<th>Data Mart</th>
<th>Facts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business, manufacturing</td>
<td>Supplies</td>
<td>Purchases, stock inventory, distribution</td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td>Packaging, inventory, delivery, manufacturing</td>
</tr>
<tr>
<td></td>
<td>Demand management</td>
<td>Sales, invoices, orders, shipments, complaints</td>
</tr>
<tr>
<td></td>
<td>Marketing</td>
<td>Promotions, customer retention, advertising campaigns</td>
</tr>
<tr>
<td>Finance</td>
<td>Banks</td>
<td>Checking accounts, bank transfers, mortgage loans, loans</td>
</tr>
<tr>
<td></td>
<td>Investments</td>
<td>Securities, stock exchange transactions</td>
</tr>
<tr>
<td></td>
<td>Services</td>
<td>Credit cards, bill payment through standing orders</td>
</tr>
<tr>
<td>Health service</td>
<td>Division</td>
<td>Admissions, discharges, transfers, surgical operations, diagnosis, prescriptions</td>
</tr>
<tr>
<td></td>
<td>Epidemiology</td>
<td>Diseases, outbreaks, treatments, vaccinations</td>
</tr>
<tr>
<td>Transportation</td>
<td>Goods</td>
<td>Demand, supply, transport</td>
</tr>
<tr>
<td></td>
<td>Passengers</td>
<td>Demand, supply, transport</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>Traffic management</td>
<td>Network traffic, calls</td>
</tr>
<tr>
<td></td>
<td>Cust. rel. management</td>
<td>Customer retention, complaints, services</td>
</tr>
<tr>
<td>Tourism</td>
<td>Demand management</td>
<td>Ticketing, car rentals, stays</td>
</tr>
</tbody>
</table>
Facts should be enriched with additional information, such as \textit{dimensions} and \textit{measures}.

Such information can be derived from existing documentation, database schemata of source systems, users, etc.

As DW store historical information, every fact needs a \textit{historical interval}, for which the data should be stored.

Example of user requirements glossary

<table>
<thead>
<tr>
<th>Fact</th>
<th>Dimensions</th>
<th>Measures</th>
<th>History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock inventory</td>
<td>Product, Date, Warehouse</td>
<td>Stocked quantity</td>
<td>1 year</td>
</tr>
<tr>
<td>Sales</td>
<td>Product, Date, Store</td>
<td>Sold quantity, Receipts, Discount</td>
<td>5 years</td>
</tr>
<tr>
<td>Order Lines</td>
<td>Product, Date, Supplier</td>
<td>Ordered quantity, Receipts, Discount</td>
<td>3 years</td>
</tr>
</tbody>
</table>
Preliminary Workload

Together with the facts, a set of preliminary workloads should be identified.

Workloads are analysis queries the user wants to answer.

Example for workload (analysis queries)

<table>
<thead>
<tr>
<th>Fact</th>
<th>Query</th>
</tr>
</thead>
</table>
| Stock inventory | What is the average quantity of each product made available monthly in every warehouse?  
                  | Which product stocks ran out at least once last week at the same time in every warehouse?  
                  | What’s the daily trend of all the stocks grouped by product type? |
| Sales         | What’s the total amount per product sold last month?  
                  | What are the daily receipts per store?  
                  | What is the annual report of receipts per state per product? |
| Order lines   | What is the total amount of goods ordered from a specific supplier every year?  
                  | What’s the daily total amount ordered last month for a specific product type?  
                  | What’s the best discount given by each supplier last year and grouped by product category? |
Kimball and Ross propose in their DW/DM design methodology as the first step to choose business process(es) together with analysis questions that can be answered.

Example of business process in a grocery store domain:

- Management wants to better understand customer purchases as captured by the POS system.
- Business process: POS retail sales
- Allows us to analyze:
  - What products are selling?
  - In which stores?
  - On what days?
  - Under what promotional conditions?
  - etc.
Outline

1 User Requirement Analysis

2 Dimensional Fact Model

3 Conceptual Design
Why a New Model?

- **ER and OO model** are widely used as a conceptual tool for documentation and design of relational databases.
- ER/OO models serve **many purposes**, thus they are **flexible and general**.
- All types of data are **equal**.
- No difference between:
  - What is *important*.
  - What just describes the important things.
- ER/OO models are **large**.
  - 50–1000 entities/relations/classes.
  - Hard to get an overview.
- ER/OO models implemented in RDBMSs.
  - Normalized databases spread information.
  - When analyzing data, the information must be integrated/joined.
Dimensional Fact Model

OLTP Example: CS Dept/1
OLTP Example: CS Dept/2
Why a New Model?/2

- ER/OO models are not very useful in modeling DWs.
- It is now generally recognized that a DM/DW is based on a multidimensional view of the data.
- But there is still no agreement on how to realize its conceptual design.
- Very often DM design is at the logical level, i.e., star/snowflake schema is directly designed.
  - But a star schema is nothing but a relational schema.
  - Standard implementation of the multidimensional model in RDBMS.
  - Contains only the definition of a set of relations and integrity constraints!

- A better approach:
  1. design first a **conceptual model** using richer and more user-friendly language;
  2. translate conceptual model into a **logical model**.
The **Dimensional Fact Model (DFM)** is a graphical conceptual model for DM/DW design.

The aim of the DFM is to

- provide effective support to conceptual design;
- create an environment in which user queries may be formulated intuitively;
- make communication possible between designers and end users with the goal of formalizing requirement specifications;
- build a stable platform for logical design (independently of the target logical model);
- provide clear and expressive design documentation.

The conceptual representation generated by the DFM consists of a set of fact schemata that basically model facts, measures, dimensions, and hierarchies.
DFM: Facts, Measures and Dimensions

A fact is a concept relevant to decision-making processes.
- It typically models events taking place within a company, e.g.,
  - in commercial domain: sales, shipments, purchases, taking exams, . . .
  - in healthcare industry: patient transfers, discharges, surgeries, . . .
  - in financial business: stock exchange transactions, credit card balance, . . .
- It is essential that a fact has dynamic properties and evolves over time.

A measure is a numerical property of a fact and describes a quantitative fact aspect that is relevant to analysis, e.g.,
- every sale is quantified by its units sold, unit price, . . .
- exams are quantified by its grades, credit points, . . .
- bank transfers are quantified by the amount

Measures are used to make calculations and analyses

A dimension is a property of a fact with a finite domain and describes an analysis coordinate of the fact.
- Typical dimensions are
  - for the sales fact: product, store, date
  - for the patient transfer fact: patient, department, date
Example: Sales facts in a store

- Fact: 10 packages of milk were sold for $25 on 10.10.2013 in the DM store.

In the DFM
- A fact expresses a **many-to-many relationship** between its dimensions.
- Facts, dimensions, and measures are **first-class citizens**

In the ER model these concepts are not first-class citizens
- Fact is a relationship, dimensions are entities, measures are attributes of relationships.
The general term **dimensional attributes** stands for the dimensions and other attributes that describe the dimensions.

- e.g., a product is described by its type, by the category to which it belongs, by its brand, and by the department in which it is sold.

**Dimensional attributes have always discrete values**

**Relationships between dimensional attributes are expressed by hierarchies**

A **hierarchy** is a directed tree: nodes are **dimensional attributes** and arcs model **many-to-one associations** between dimensional attributes.

- **The dimension itself** is at the **root** of the tree
- **All other dimensional attributes** are (direct or indirect) descendents
- **The root** defines the **finest granularity** level; the other attributes are at a coarser granularity
**Example:** Fact schema for sales events enhanced with dimensional attributes

- Many-to-one relationships (i.e., hierarchies) from parent nodes to child nodes
- Hierarchies describe functional dependencies, e.g.,
  - product $\rightarrow$ type, type $\rightarrow$ category, category $\rightarrow$ department
  - product $\rightarrow$ brand, brand $\rightarrow$ brandCity
DFM vs. ERM
DFM: Naming Conventions

- All attributes and measures within a fact schema must have different names.
- You can differentiate similar names, if you qualify them with the name of the dimensional attribute that comes before them in hierarchies.
  - e.g., storeCity and brandCity
- Attributes names should not explicitly refer to the fact they belong to.
  - Avoid shipped product and shipment date.
- Attributes with the same meaning in different fact schemata should have the same name.
A **primary event** is a particular occurrence of a fact that is identified by one tuple with a value for each dimension and each measure.

- e.g., 10 packages of milk were sold for a total of $25 on 10/10/2013 in the SmartMart store.

Each combination of a set of dimensional attribute values identifies a **secondary event** that aggregates each measure over all corresponding primary events.

- e.g., \( \text{product: 'milk', storeCity: 'Bozen', month: '10/2013'} \) identifies a secondary event that aggregates all sales of milk in October 2013 in Bozen.

**Hierarchies** are used to define the way how to aggregate primary events and effectively select them for decision-making processes.

- The **root** of the hierarchy defines the **finest aggregation granularity**.
- The other dimensional attributes correspond to a **gradually increasing granularity**.
Primary and Secondary Events/2

- Primary events: (product, store, date)
- Secondary events: (product type, store city, month), (product type, month)
**DFM: Descriptive and Optional Attributes**

- **Descriptive attributes** store additional information (i.e., a property) about dimensional attributes, e.g., address, phone number
  - Usually not used for aggregation
  - One-to-one association to a dimensional attribute, and always a leave node
- Some arcs in a fact schema can be **optional**
  - e.g., diet has a value (cholesterol-free, gluten-free, sugar-free, ...) only for food; for other products the value is null
**DFM: Convergence**

- In a convergence, two (or more) dimensional attributes are connected by two (or more) distinct directed paths.
- Each path still represents a functional dependency.
  - e.g., \(\ldots \rightarrow \text{salesDistrict} \rightarrow \text{country}, \ldots \rightarrow \text{state} \rightarrow \text{country}\)

![Diagram of DFM: Convergence]
A shared hierarchy is a shorthand to denote that a part of a hierarchy is replicated. If a hierarchy were replicated, names would have to be qualified with the dimension in order to avoid ambiguity.

Roles are used to specify the meaning if a shared hierarchy starts at the dimension attribute, e.g., calling and called for telNumber.

Otherwise, the meaning is specified by the parents, e.g., warehouse city vs. customer city.
DFM: Multiple Arc

- A **multiple arc** models a **many-to-many** association between two dimensional attributes (and not many-to-one)
- Aggregation along multiple arcs needs particular care
  - e.g., how much did Rizzi sell, how much Rizzi and Golfarelli together?

![Diagram](image)

<table>
<thead>
<tr>
<th>Facts &amp; Crimes</th>
<th>Golfarelli, Rizz</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sounds Logical</td>
<td>Golfarelli</td>
<td>5</td>
</tr>
<tr>
<td>The Right Measure</td>
<td>Rizzi</td>
<td>10</td>
</tr>
<tr>
<td>Facts: How and Why</td>
<td>Golfarelli, Rizz</td>
<td>4</td>
</tr>
<tr>
<td>The Fourth Dimension</td>
<td>Golfarelli</td>
<td>8</td>
</tr>
</tbody>
</table>

**How much did Rizzi sell?**
An **incomplete hierarchy** is a hierarchy where, for some instances, one or more aggregation levels are **missing**, because they are unknown or undefined.

Different from optional arcs, where all descendant attributes are missing; here, only selected attributes are missing.
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1. User Requirement Analysis
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Conceptual Design

- Process of designing/creating a set of DFM schemata

- Requirements-driven approach
  - Designers extract detailed information about facts, measures, and hierarchies from user interviews
  - A connection between the source schema and the data mart schema is established later

- Data-driven approach
  - A conceptual schema for the data mart is created starting from the schema of data sources
  - A connection between the source schema and the data mart schema is easily established
  - A preliminary conceptual schema can be automatically derived
Requirements-driven Approach

- The DFM schemas are derived by the designer from the result of the requirements analysis (interviews, glossaries, ...)
- Design has to manipulate the interviews with users in order to extract
  - precise instructions about facts
  - measures defining those facts
  - hierarchies for those facts that can be used for aggregating
Data-driven Approach

- Conceptual design starts from the documentation of the data sources
  - ER diagrams
  - Relational schemata
  - XML schemata
  - ...

- Design steps:
  - Define facts
  - For each fact:
    - Build an attribute tree
    - Edit the attribute tree
    - Define dimensions
    - Define measures
    - Create a fact schema

- We show the design steps for ER diagrams; they work in a similar way for relational schemata and other documentation
ER Schema for Sales Example
Defining Facts

- In an ER schema, a fact my correspond either to an entity or to an n-ary relationship
- Entities that are frequently updated, such as SALE, are good candidates for facts
- Entities that represent structural domain properties are rather static, such as STORE and CITY, and are not good candidates for facts
- In the sale ER schema, we choose as a fact the SALE relationship
Building the Attribute Tree

- In an attribute tree:
  - The root corresponds to the entity/relationship identified as fact
  - Each node corresponds to a source schema attribute
  - For each node \( v \), the corresponding attribute functionally determines all the attributes corresponding to the descendants of \( v \)

- The attribute tree can be automatically constructed by recursively navigating functional dependencies expressed by identifiers and many-to-one relationships in the source schema
Example: Building the Attribute Tree
Example: Attribute Tree
Generally, not all attributes in the tree are relevant to the DM

Unnecessary levels of detail should be removed

- **Prune** nodes and the entire sub-tree, e.g., state or size
- **Graft** individual nodes by connecting children with the parent node, e.g., saleReceiptNum
Edited Attribute Tree
Defining Dimensions

- **Dimensions** are selected from the root child nodes of the attribute tree, e.g., `product`, `store`, `date`.

- Selecting dimensions is crucial since it defines the **granularity of primary events**.

- **Time** should always be a dimension.
  - Typically represents **validity time**, i.e., time when an event occurs in the business domain.
  - **Transaction time**, i.e., time when an event is stored in the DM, is normally not considered relevant for decision making.
Defining Measures

- Attributes are usually from the numeric attributes which are root children, e.g., quantity, unitPrice.
- Otherwise, aggregation operators (SUM, AVG, MAX, ...) might be applied on primary events to obtain measures.
- A fact may also be without measures.
Generating DFM Schemata

- The attribute tree can now be automatically translated into a DFM schema including the dimensions and measures specified in the preceding phases.
  - Hierarchies correspond to sub-trees of the attribute trees with their roots in dimensions.
  - Fact names correspond to the names of entities chosen as facts.
Summary

- Requirements analysis to solicit business users needs, e.g., using interviews or glossary-based analysis
  - Results in facts/business processes and workload/queries
- There is a need for new models and modelling approaches in DWs, since ER/OO models are not very useful
  - too flexible and general resulting in complex models
- DW/DM design should be done in 2 steps:
  - conceptual design produces a conceptual model;
  - logical design transforms conceptual model into logical model.
- Conceptual design is frequently skipped.
- DFM is a graphical conceptual model to support the conceptual design.
  - Distinguishes between dimensions, facts, and measures
- DFM schemas can be created from the user requirements (requirements-driven approach) or derived from the documentation of the data sources (data-driven approach)