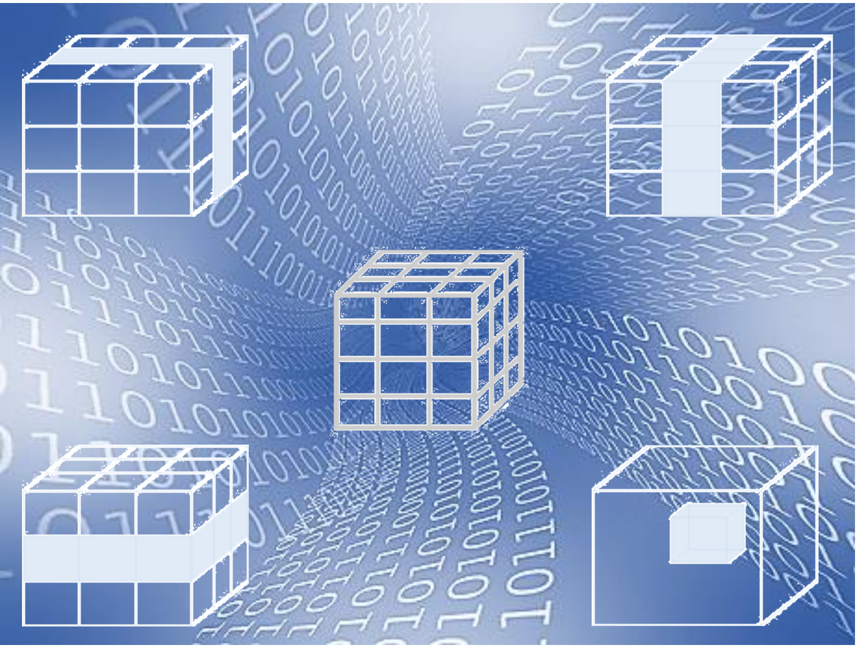
Prof. Dr. Bastian Amberg
School of Business & Economics
Department of Information Systems

Freie Universität Berlin



Business Intelligence

04 Data Warehouse Modeling II

& First Short Introduction to Data Mining

Prof. Dr. Bastian Amberg
(summer term 2024)
10.5.2024

Schedule

Freie Universität Berlin

	Wed., 10:00-12:00			Fr., 14:00-16:00 (Start at 14:30)		Self-study	
W1	17.4.	(Meta-)Introduction		19.4.		Python-Basics	Chap. 1
W2	24.4.	Data Warehouse – Overview	& OLAP	26.4.	*[Blockveranstaltung SE Prof. Gersch]*		Chap. 2
W3	1.5.			3.5.	Data Warehouse Modeling I		Chap. 3
W4	8.5.	Data Warehouse Modeling I	& II	10.5.	Data Mining Introduction		
W5	15.5.	CRISP-DM, Project understanding		17.5.	Python-Basics-Online Exercise	Python-Analytics	Chap. 1
W6	22.5.	Data Understanding, Data Visualization		24.5.	*No lectures, but bonus tasks*		Chap. 2
W7	29.5.	Data Preparation		31.5.	*1.) Co-Create your exam* *2.) Earn bonus points for the exam*		
W8	5.6.	Predictive Modeling I		7.6.	Predictive Modeling II (10:00 -12:00)	BI-Project	Start
W9	12.6.	Fitting a Model I		14.6.	Python-Analytics-Online Exercise		|
W10	19.6.	*Guest Lecture*		21.6.	Fitting a Model II		|
W11	26.6.	How to avoid overfitting		28.6.	What is a good Model?		|
W12	3.7.	Project status update Evidence and Probabilities		5.7.	Similarity (and Clusters) From Machine to Deep Learning I		|
W13	10.7.			12.7.	From Machine to Deep Learning II		|
W14	17.7.	Project presentation		19.7.	Project presentation		End
					Klausur 1.Termin ~ 22.7. bis 3.8. *Klausur 2.Termin ~ 23.9. bis 5.10.*	Projektbericht	

Basics

Main Part

Deep-ening

Case Study

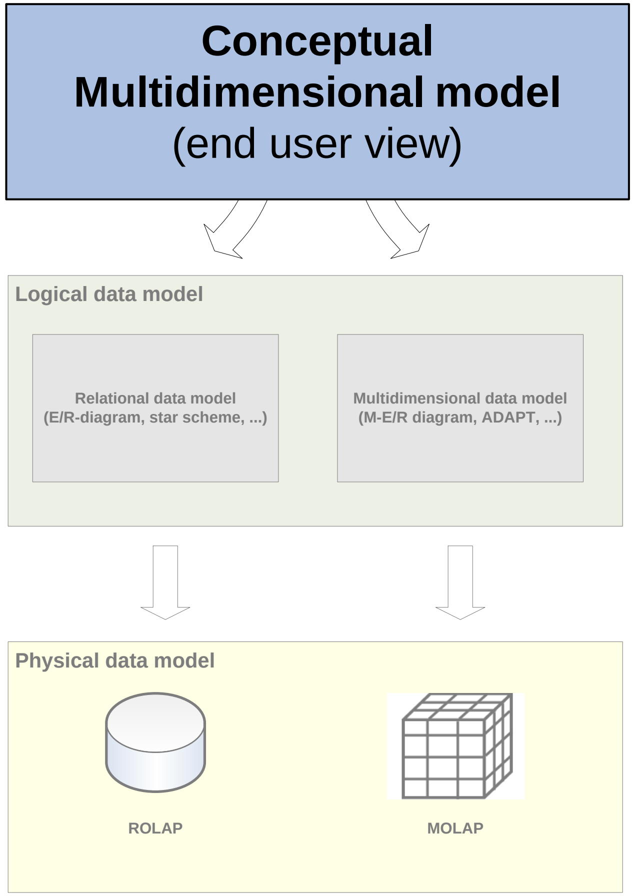
Ref.

Last lesson

vs. OLTP

- ✓ Online Analytical Processing (OLAP)
- ✓ How can multidimensional data models be **developed** and **stored**?

1. Identify **facts** and **dimensions**
2. Create a **conceptual** data model
3. Derive a **logical** data model from the semantic model
4. Derive a **physical** data model from the logical model



Dimension = *finite* **set of categories** which are semantically related to each other with respect to business matters

Categories of one dimension represent a **different levels of aggregation** of the associated business *measures* (facts)

For example, dimension "date"
Four categories: day ⇒ month ⇒ quarter ⇒ year

Umsatz

Ref.

Agenda

Continuation Data Warehouse Modeling

Basic Elements of multidimensional modeling

Conceptual modeling

Logical modeling

Physical modeling

Ref.

Conceptual Modeling

Dimensional fact model (or fact scheme)

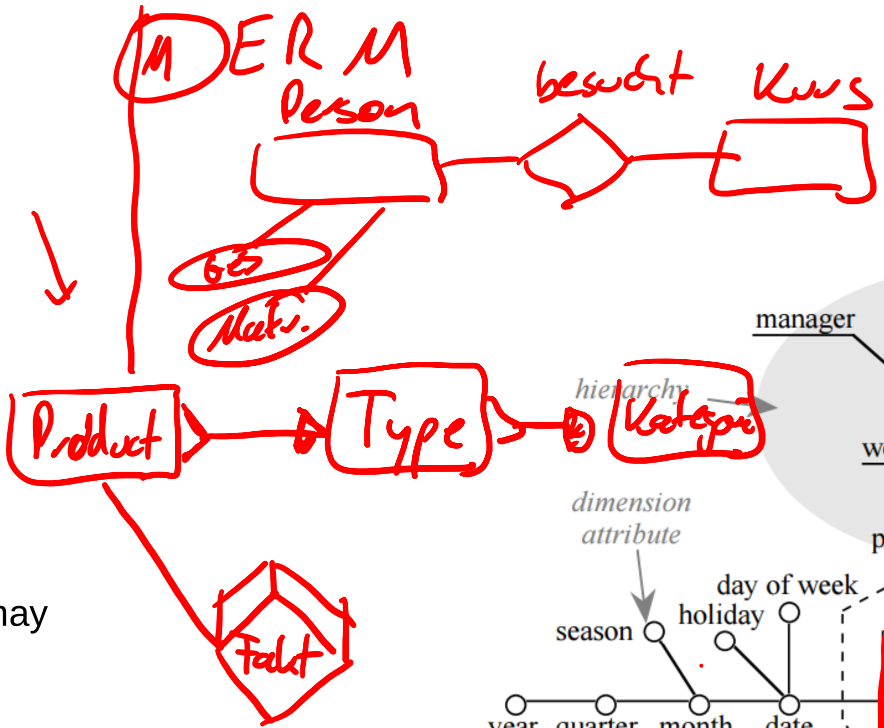
Wdh.

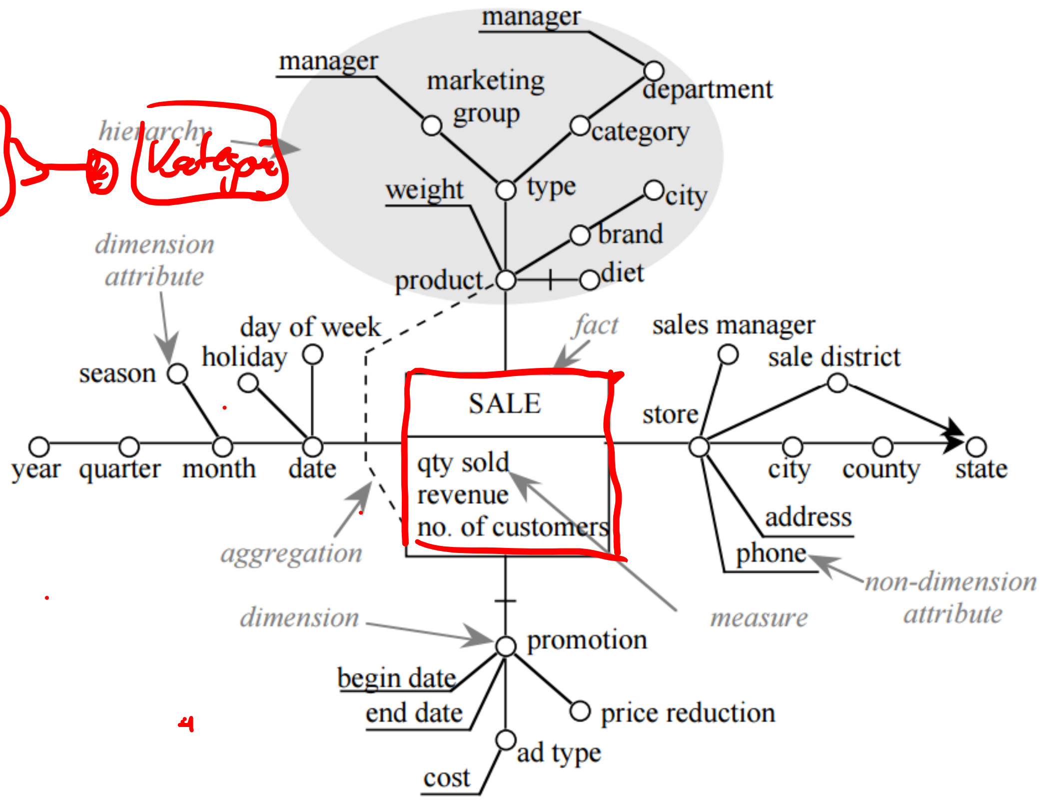
Categories of a dimension arranged in a non-cyclic graph, directed between all-category and log-categories

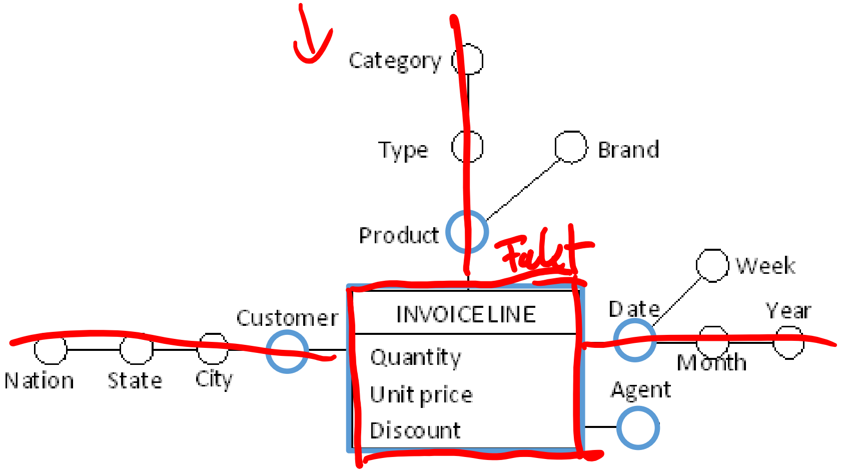
Categories can have an arbitrary number of (non recursive) relations between each other

Several aggregation paths (e.g., sum/count/mean) may be included in the graph

Hierarchies are discrete attributes and define the granularities of facts (i.e., product -> type -> category)







Ref. Golfarelli et al. (1998), helpful reading (with exercises) by A. Prosser & M.-L. Ossimitz, Hahne (2006)

Image: see ref. (link), Matteo.golfarelli (2010) | Wikimedia

Non-& Cross-dimensional attributes

Dimensional fact model

There may be **various types of relations** between individual categories of one (or more) dimension(s)

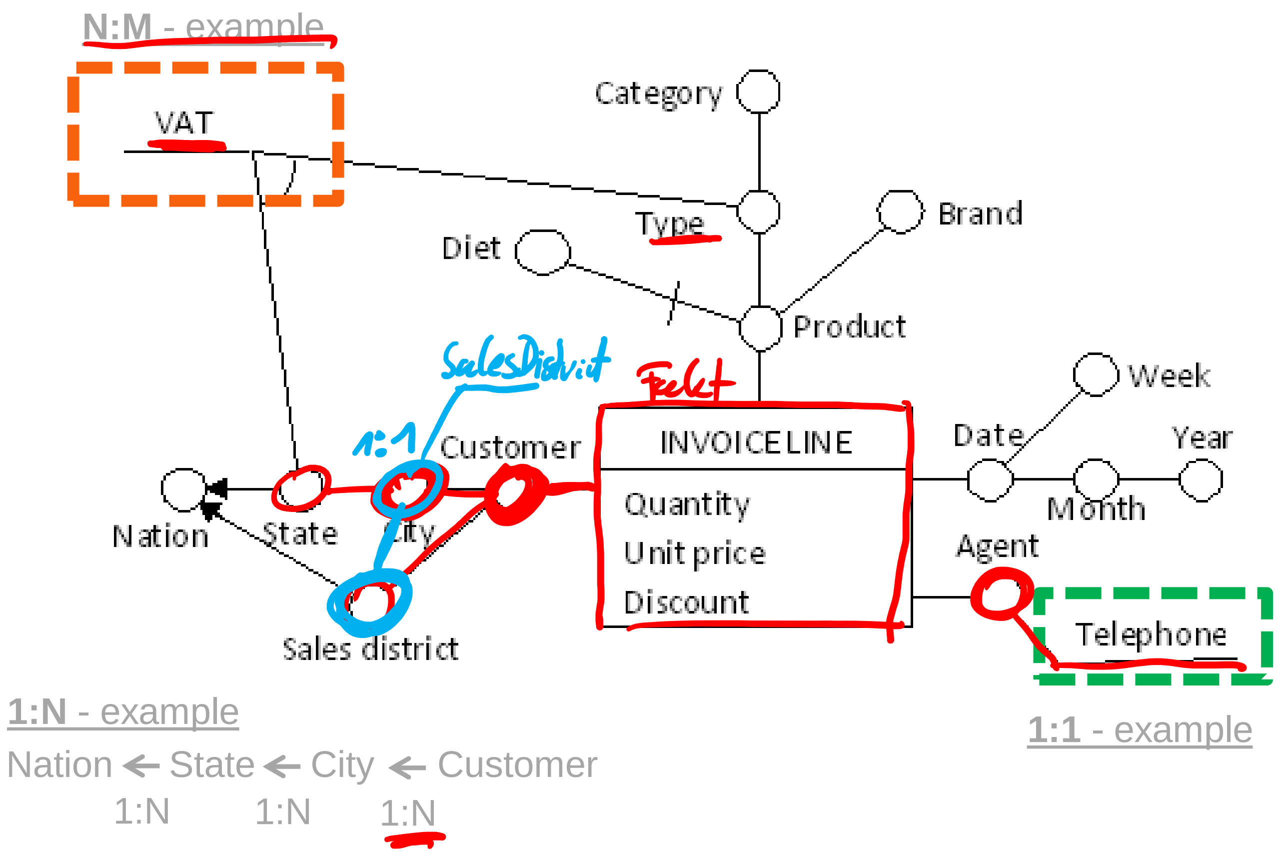
Categories having 1:1 relations can be summarized into a single category

When previous categories become non-dimensional, **descriptive attributes**
Non-dimensional attributes provide additional information and have 1:1 relations with the corresponding categories (phone-No. cannot be aggregated)

OLAP-compliant queries encompassing non dimensional attributes are generally not supported

Categories having **1:N** or N:M relations

When value is defined by multiple categories (e.g., product type and state. For instance, VAT for water or books in Germany vs. USA) they become cross-dimensional attributes



Ref. Golfarelli et al. (1998), helpful reading (with exercises) by A. Prosser & M.-L. Ossimitz, Hahne (2006)

Image: Matteo.golfarelli (2010) | Wikipedia (cc by-sa 3.0)

Exercise

Conceptual Modeling (Dimensional fact model)

Freie Universität Berlin

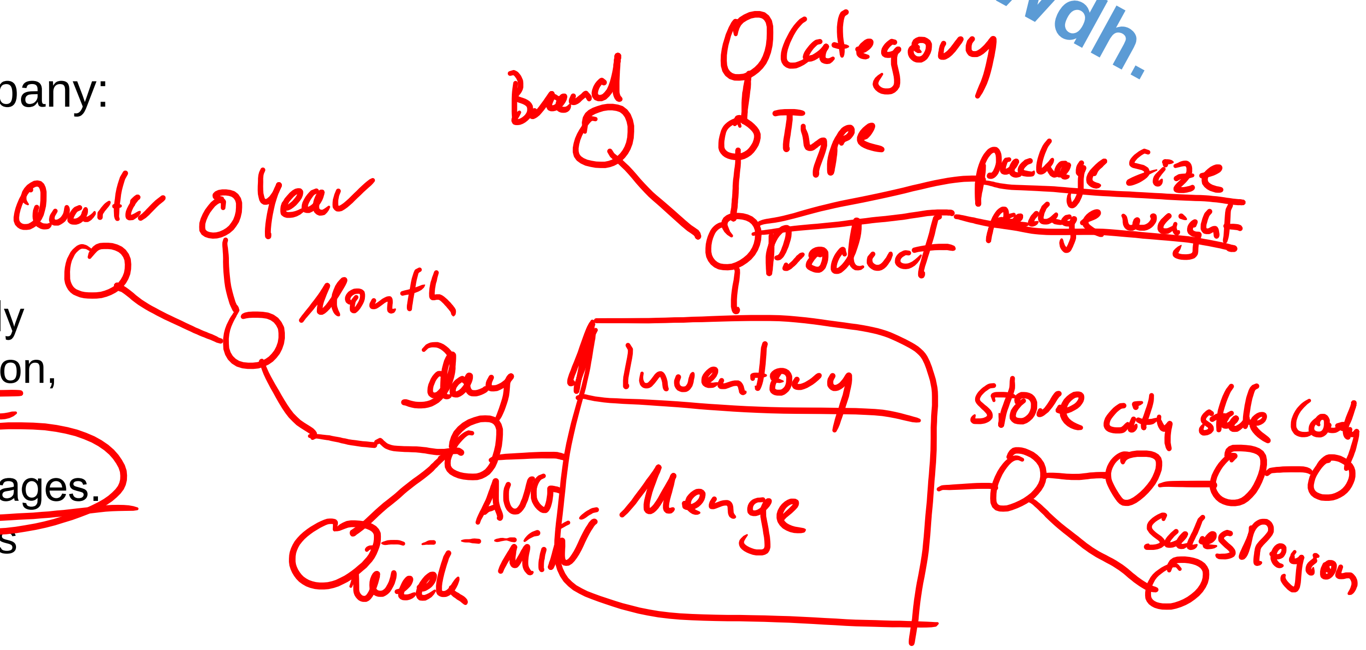
Wdh.

Design a **conceptual model** for the local Food Company:

Conny's Corner Shop

Your managers need to keep themselves up to date on the number of items in the company's inventory. They especially want to keep an eye on their products with regards to location, and time.

- Conny's Corner Shop sells a range of snacks and beverages. Both categories have different types of products, such as juices and water, as well as prezels and crackers.
- The products are sold under different brands.
- Products have different package types, sizes, and weights.
- They store products in different stores across Europa



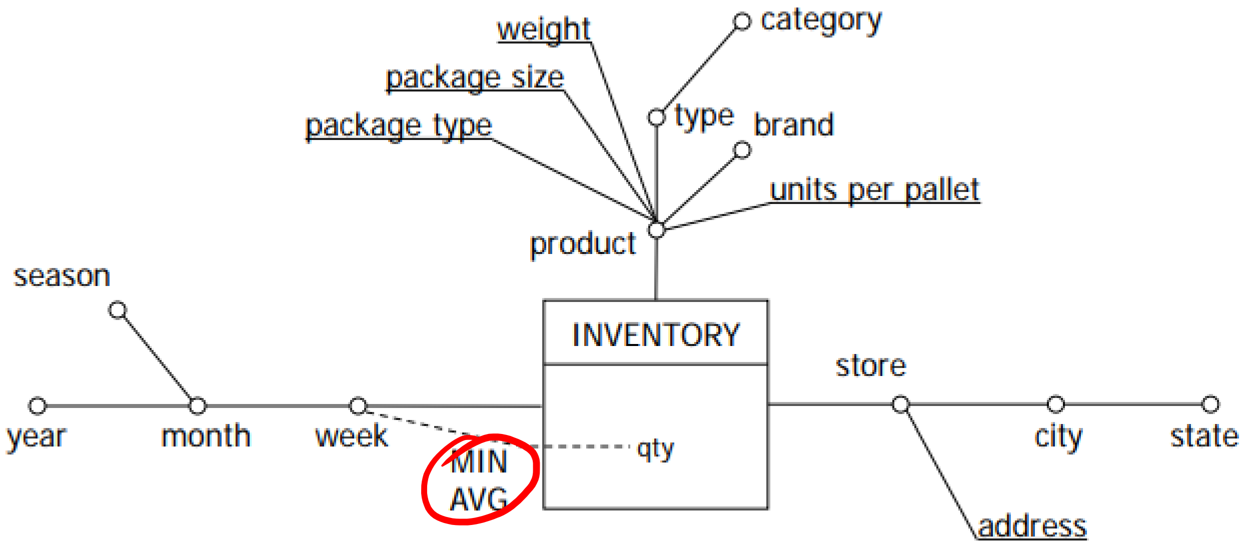
10 Min.

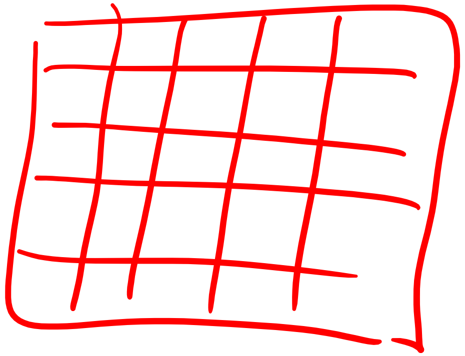
Show your conceptual model as a dimensional fact model. Make reasonable assumptions if necessary.

Ref.

Exercise

One solution for the exercise





Ref.

Identifying fact groups

Single Star Scheme

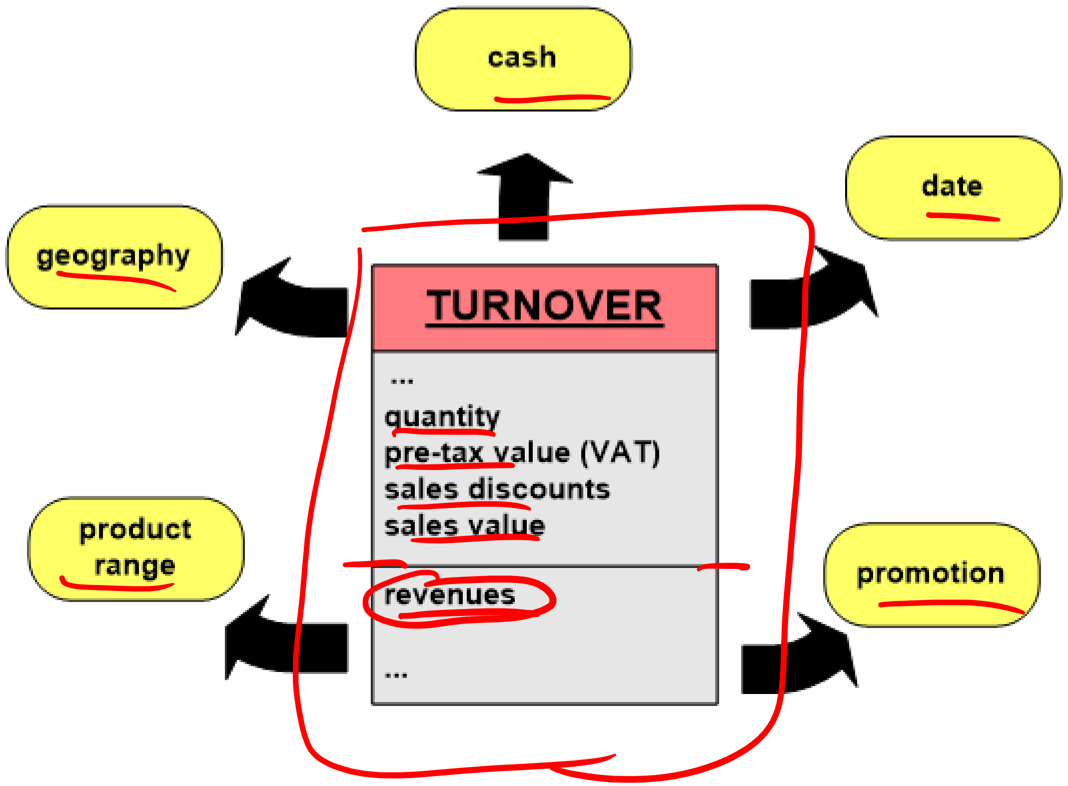
Wdh.

A graphical overview should be created for each fact group

single star scheme

Distinction between materialized facts and derived facts should be drawn

High level of abstraction:
aggregation formulas are commonly not modeled



Remember: **Fact group = set of facts** featuring *a common set* of dimensions

Ref.

Combining fact groups

Multiple Star Scheme

Wdh.

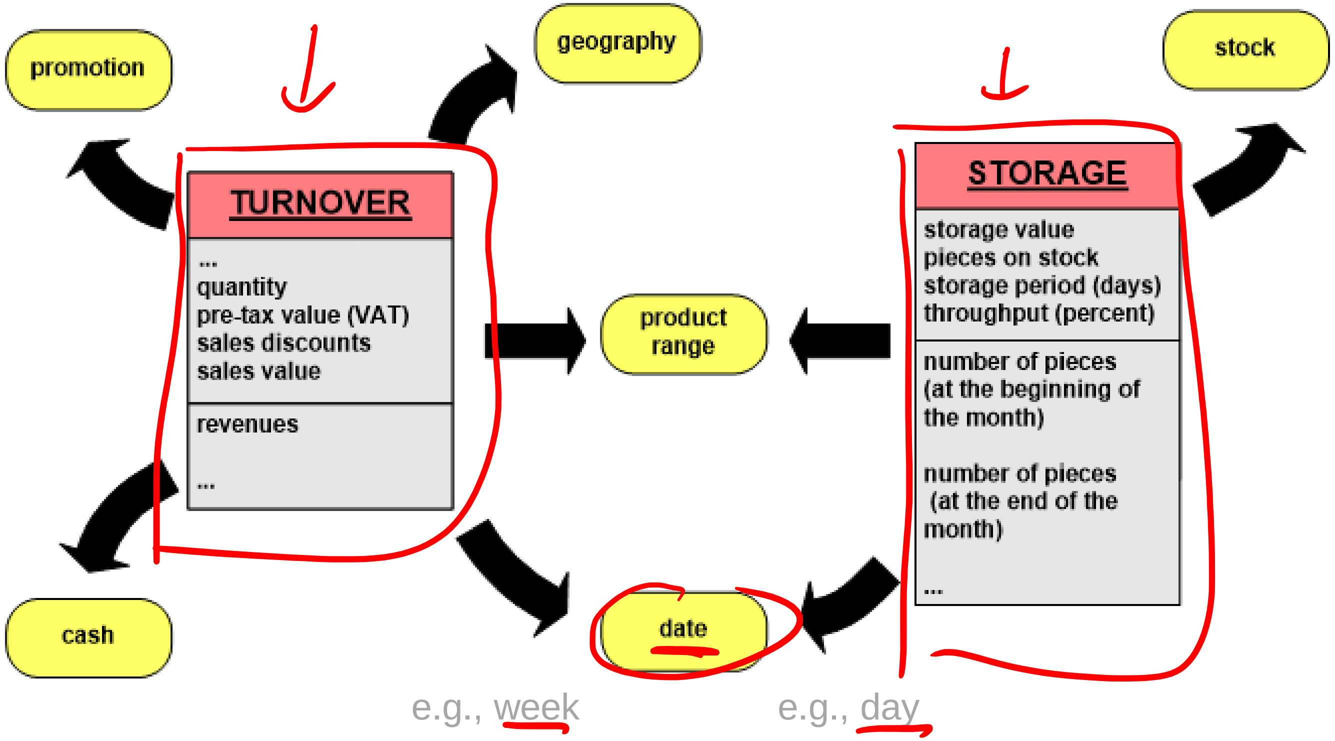
A data warehouse data model encompasses a number of fact groups (**multiple star scheme**)

The sets of associated dimensions of different fact groups may overlap.

Different fact groups may use different log-categories with respect to one common dimension

- e.g., actual / debit values:
  - Actual facts: log-category of dimension date: day
  - Target facts: log-category of dimension date: month

Category used as log-category should be specified in the model (at least if standard log-category is not used)



Ref.

Agenda

Continuation Data Warehouse Modeling

Basic Elements of multidimensional modeling

Conceptual modeling

Logical modeling

Physical modeling

Ref.

Basic tasks with logical modeling

Logical modeling is about adapting the general conceptual schema to the applied database technology

- **Relational database technology**
  ⇒ ER diagrams, …
- **Multidimensional database technology**
  ⇒ M-ER diagrams, ADAPT diagrams, …

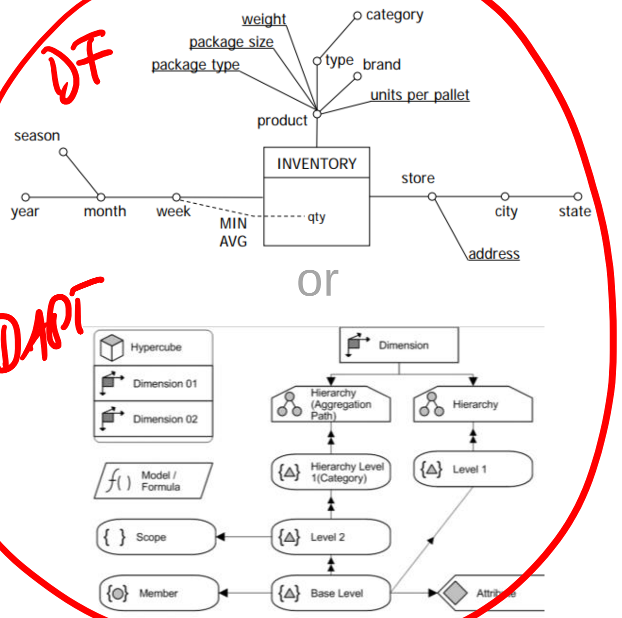
  M-ER: Multidimensional Entity-Relationship
  ADAPT: Application Design for Analytical Processing Technologies
  (Both also usable as starting point for relational DB design)

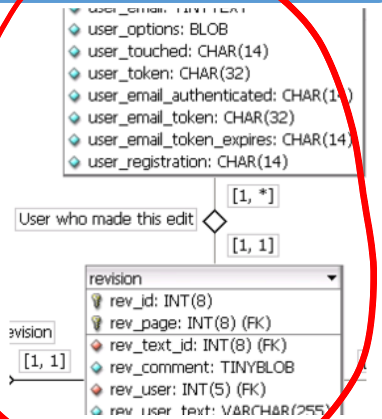
Star Scheme is the standard way of logical modeling concerning **relational DBMS**

Business Term → Technical Term

DF

ADAPT





Excursus: Genealogy of Relational Database Management Systems 

Image: AutumnSnow (2008) | Wikimedia (cc by sa 3.0)

Properties of star scheme models

{Date, Store, Product}

Dim_Store

ID	Store_Number	State_Province	Country
1	1	Berlin	
2 …	… 13	…	…

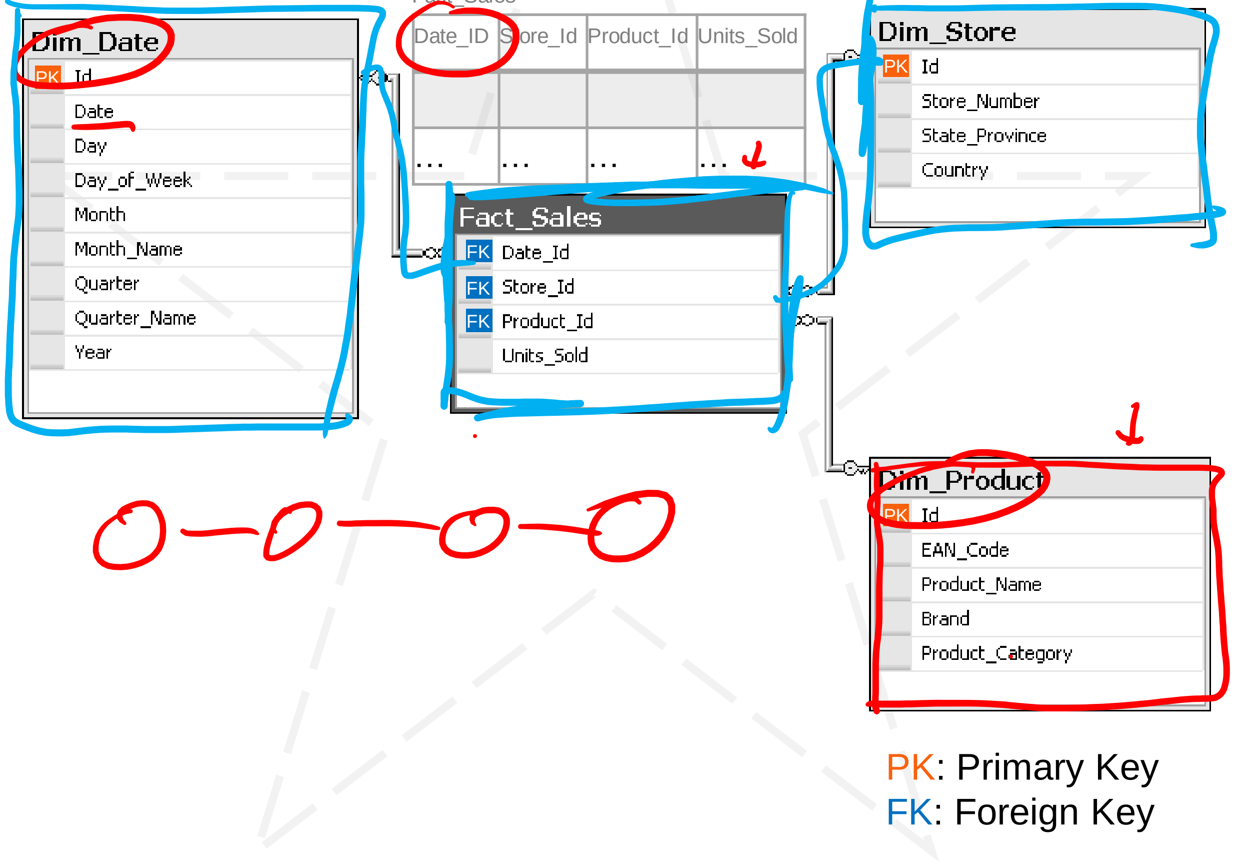
for better readability, columns are displayed as rows

A number of fact tables are associated with a set of dimension tables each (via **unique keys**)

- One dimension is mapped to exactly one relation
- Primary key of a fact table consists of the keys of the associated dimensions
- Keys of the dimension tables are usually "artificially" created (e.g. serial numbers)
- 1:m type relations between dimensions and facts

Fact_Sales

Date_ID	Store_Id	Product_Id	Units_Sold
…	…	…	…



PK: Primary Key
FK: Foreign Key

Typical "multi-join" query for star schemes:

```
SELECT
  D1.State_Province, D2.Month,
SUM (F1.Units_Sold)
FROM Dim_Store D1, Dim_Date D2, Fact_Sales F1
WHERE
  D1.Id = F1.Store_Id AND
  D2.Id = F1.Date_Id
GROUP BY D1.State_Province, D2.Month
```

Result?

Ref.

Image: SqlPac (2008) | Wikipedia (cc by-sa)

Simple star scheme

Store City State Country

Attribut

Mkt_01 _02

GEOGRAPHY

MKT_ID	MKT_DESC	MKT_ADR	STATE	COU	MGR_MKTG	MGR_MKTG_ADR	REGION_MKTG	REGION_BUY
1	Market#1	Pfaustr 1A	Hesse	GER	Heine R.	+49 (2203) 107-0	reg A	central
2	Market#2	Südstr. 11	Hesse	GER	Schneider S.	......	reg B	central
3	Market#3	Nordstr. 7	Bavaria	GER	Jose R.	...	reg B	south
4	Market#4	...	...	...	...	...	...	...

1:M

CASH

1:M

PROMOTION

1:M

TURNOVER

DAY_ID	MKT_ID	PROD_ID	PROM_ID	CASH_ID	TO_INIT_VAL	TO_QUANTITY	TO_VAT_VAL	TO_DISC	TO_SAL_VAL
113	1	99	2	1	10	100	11	0.05	10
113	1	100	2	1	55	240	24	0.03	55
113	1	45	3	2	3	100	4	0.03	3
113	1	102	1	1	1850	20000	400	0.05	1850
113	1	103	2	...	...	...	...	...	...
	...	...	...	...	...	...	...	...	...

201 1000 2000

M:1

PRODUCTS

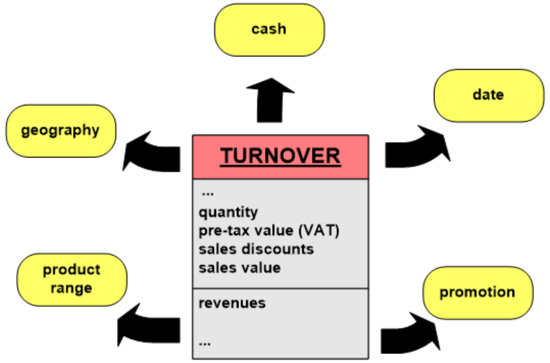
M:1

DATE

DAY_ID	DAY_DESC	DNO_SER	SWITCH_FLAG	WEEK	MONTH	WEEKNO	QUARTER	YEAR
...	...	...	...	...	...	...	...	...
110	31-12-98-Thu	1460	n	W53	M12/Q4/98	53	Q4/98	1998
111	01-01-99-Fr	1461	n	W53	M01/Q1/99	1	Q1/99	1999
112	02-01-99-Sa	1462	j	W53	M01/Q1/99	1	Q1/99	1999
113	03-01-99-Su	...	j	...	...	...	...	...
...	...	...	...	...	...	...	...	...

60

201 Null Null Null Null M01\Q1\95 Null " 2024



Category or descriptive attribute?

Hierarchies?

Performance for aggregation functions?

Ref.

Simple star schemes

Pros and Cons

PRO

Simple, intuitive model

Not many physical join-operations needed

Not many physical tables needed
⇒ maintenance easy
⇒ Extract, Transform, Load (ETL) easy

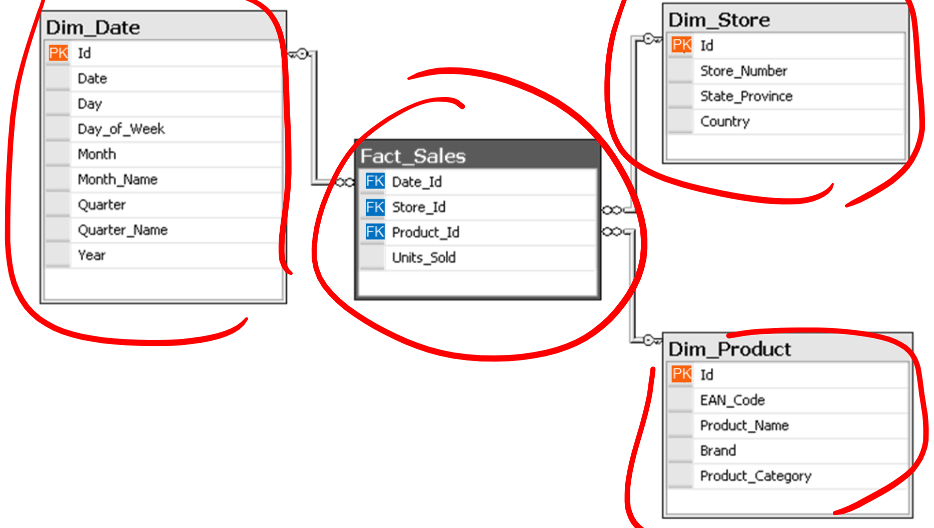
CON

Large dimension tables may cause **bad response times**

Creation of materialized views (aggregated summary tables) difficult
⇒ wrong aggregate values may be calculated due to **multiple counting of entries**

Changes of the conceptual model cause extensive reorganization efforts on the tables ⇒ versioning of meta data required

Redundancy



PK: Primary Key
FK: Foreign Key

Ref.

Variants of the star scheme

Snowflake scheme:

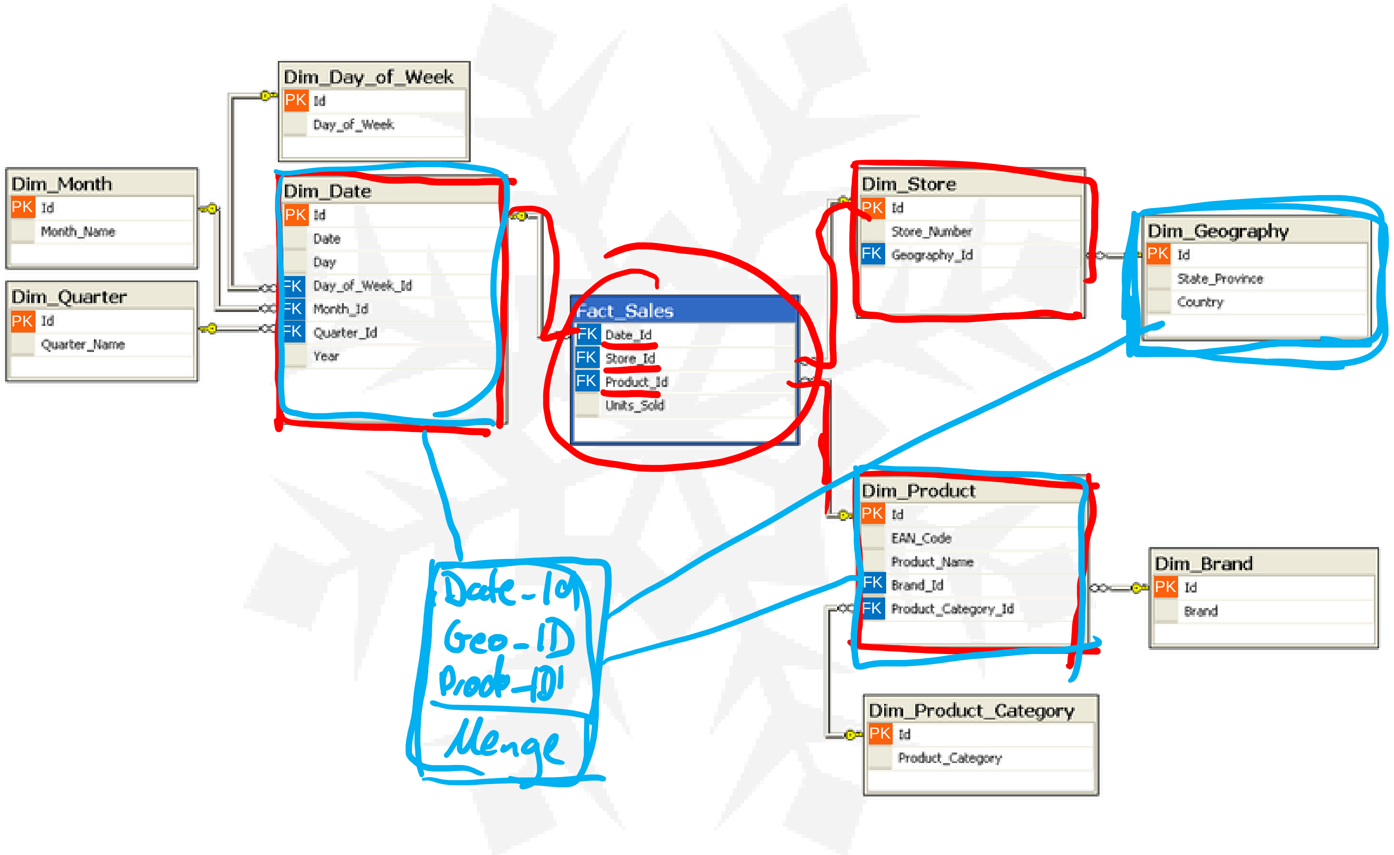
- **Normalization** of the dimensional tables of a star scheme (see also example on next slide)
- Dimensional tables are broken down into several small lookup-tables ⇒ no double entries

Consolidated star scheme:

- Basic idea: storage of aggregate values **within the fact tables** (“in-table aggregation”)
- Requires level attributes within the dimensional tables
- Provides good response times ⇒ calculations displaced to ETL-procedure (extract, transform, load)

Fact constellation scheme:

- Variant of consolidated star schemes (avoids level-attributes, uses additional fact tables for storage of aggregated values)



PK: Primary Key
FK: Foreign Key

Ref.

Image: Alan ffm (2012) | Wikimedia (cc by-sa 3.0)

Snowflake scheme

LU_COUNTRY

COU_ID	COU_DESC	COU
1	Germany	GER
2	Austria	AUT

1:M

LU_REGION_BUY

REGBUY_ID	REGBUY_DESC	COU_ID
1	AUT / EAST	2
2	GER / SOUTH	1
…	…	…

1:M

1:M

LU_REGION_MARKETING

REGMKTG_ID	REGMKTG_DESC	COU_ID
1	AUT/REG A	2
2	AUT/REG B	1
…	…	…

LU_STATE

STATE_ID	STATE_DESC	COU_ID
1	Bavaria	1
2	Hesse	1
…	…	…

LU_MARKETING_MANAGER

MKTG_ID	MGR_MKTG_DESC	MGR_MKTG_ADR	REGMKTG_ID
1	Heine R.	+49 (2203) 107-0	3
2	Schneider S.	……	4
3	Jose R.	…	4
4	…	…	…

1:M

1:M

1:M

LU_MARKET

MKT_ID	MKT_DESC	MKT_ADR	STATE_ID	MKTG_ID	REGBUY_ID
1	Market#1	Pfaustr 1A	3	1	3
2	Market#2	Südstr. 11	3	3	3
3	Market#3	Nordstr. 7	1	2	4
4	Market#4	…	…	…	…

1:M

TURNOVER

GEOGRAPHY

Hierarchies? ✓

Storage of aggregated values?

Ref.

Snowflake scheme

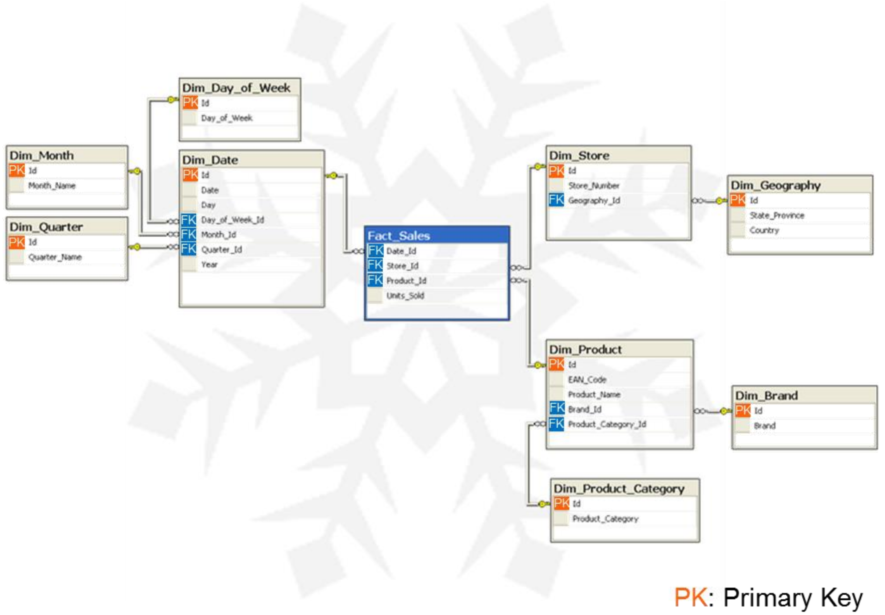
Pros and Cons

PRO

- Good support of materialized views
- Browsing can be easily implemented based on snowflake schemes
- No redundancy within the dimension tables

CON

- More physical join operations required
- More physical tables required
- Higher level of complexity
  - ETL-process
    - Maintenance
    - SQL-queries



PK: Primary Key
FK: Foreign Key

Ref.

Agenda

Continuation Data Warehouse Modeling

Basic Elements of multidimensional modeling

Conceptual modeling

Logical modeling

Physical modeling

Ref.

Excursus

Physical modeling

Database architectures

Physical implementation of logical schemata in a database system.

Relational database

usually denormalized structure for storage (star scheme)

„virtual cube"

Examples: MS Access, see Genealogy of RDBMS for more

…..
…..
…..
…..

3x3
x3

Z.B. Absatz, Dimensionen: Monat (3), Kunde (3), Artikel (3)

Multidimensional database

(precalculated) data stored in multidimensional data structures on OLAP server

cube on server

Examples: IBM Cognos TM1, Oracle Hyperion/Essbase, Jedox

Client-based files

small extracts of data are held on clients

cube on client

2·9 + 1·3 + 1

3. Monat
2. Kunde
1. Artikel

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
K1	K2	K3	K1	K2	K3	K1	K2	K3	K1	K2	K3	K1	K2	K3	K1	K2	K3	K1	K2	K3	K1	K2	K3	K1	K2	K3
Artikel 1			Artikel 2			Artikel 3			Artikel 1			Artikel 2			Artikel 3			Artikel 1			Artikel 2			Artikel 3		
Monat 1									Monat 2									Monat 3								

Select and fine tune the used DBMS technology

Building the database using the specific data definition language (e.g.: SQL-DDL-commands)

Decide on how to index, partition, denormalize and partly pre-aggregate the data.

```
CREATE TABLE employees (
id INT(6) AUTO_INCREMENT PRIMARY KEY,
first_name VARCHAR (50) not null,
last_name VARCHAR (75) not null,
age INT(3) not null,
dateofbirth DATE not null )
```

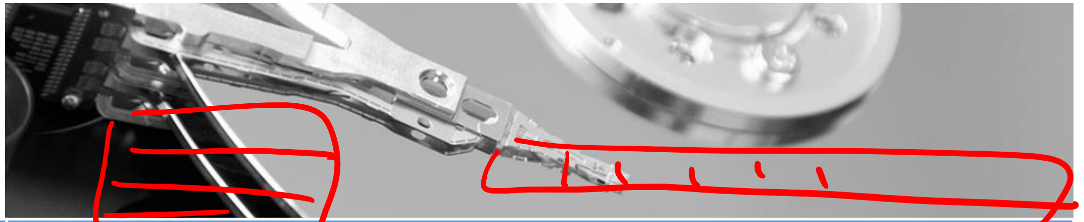
Ref.

Images: Vornberger/Müller (2001), Teller/McMillan (1998)

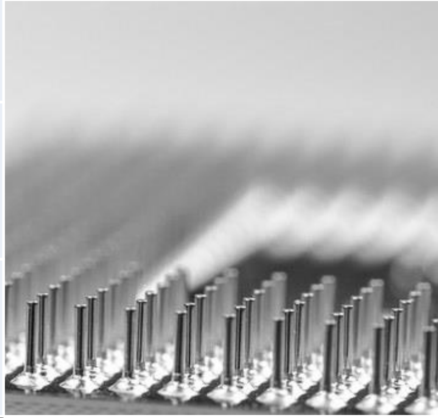
Excursus

Physical modeling

OLAP architectures



OLAP - architectures		STORAGE		
		RDBMS	MDBMS	client-based
PROCESSING	SQL	ROLAP (thin client)	-	-
	multidimensional server engine	ROLAP (thin client)	MOLAP (thin client)	-
	client multidimensional engine	ROLAP (fat client)	MOLAP (fat client)	DOLAP (fat client)



HOLAP

MOLAP = multidimensional OLAP (data in cubes)

ROLAP = relational OLAP

DOLAP = desktop OLAP

Recent developments in data warehousing, see article “Paradigmenwechsel: Data Warehouses für die Cloud“ *Kursmaterial > Readings/Übungen*

Ref. e.g., Jukic et al. (2008)

Fragen?

✓ Data Warehouse Modeling

Exercise

Conceptual Modeling and Logical Model (Star Scheme)

Design a **logical model** for the local Food Company:

Conny's Corner Shop

Your managers need to keep themselves up to date on the company's situation. They especially want to keep an eye on their products with regards to location, and time.

- Conny's Corner Shop sells beverages and snacks. Both categories have different types of products, such as juices and water, as well as prezels and crackers. The products are either branded as strictly vegan or organic (bio).
- Products are sold in different cities, regions and EU-countries
- Most managers are interested in quantities, income and discounts of sales.

SALES

10 Min.

Create a simplified Star Scheme (logical model) with tables/relations.
Use your conceptual model as input.

Outlook next lesson

Data Mining Introduction

Where are the limits of the handling of data considered so far?

(1) The need for data mining

(2) From business problems to data mining tasks

(3) Supervised vs. unsupervised methods

vs Reinforcement learning

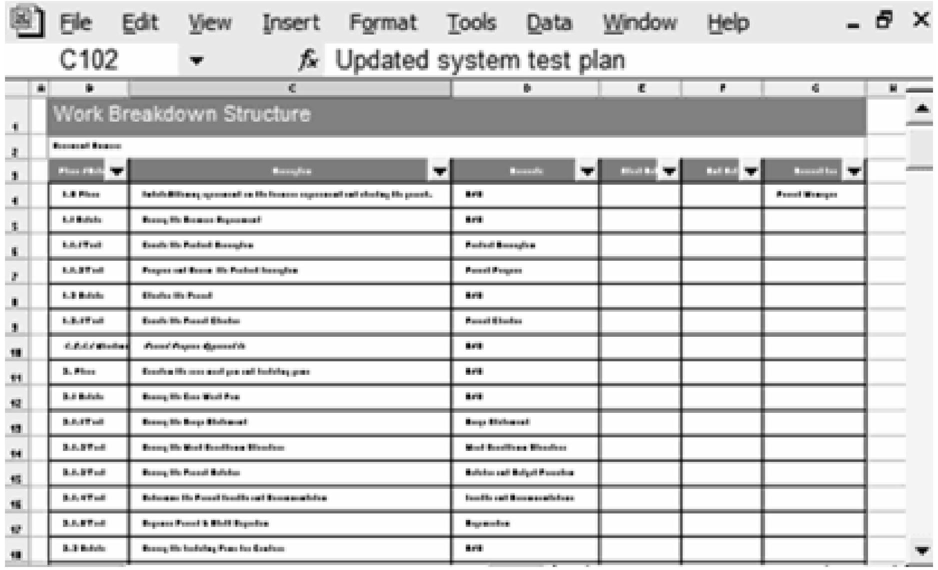
"Data mining is the analysis of (often large) observational data sets to find unsuspected relationships and to summarize the data in novel ways that are both understandable and useful to the data owner."

(Hand, Mannila, Smyth (2001), Principles of Data Mining

The need for data mining

"80% of the knowledge of interest in a business context can be extracted from data using **conventional tools**." (Lusti)

- reporting
- query-languages (SQL, QBE, …)
- OLAP and spreadsheets



Disadvantages of conventional tools:

- Often, merely simple questions can be answered
- OLAP: query-focused and low complexity of analysis
  e.g., performance changes are visible, but what about the overall context/ reasons?
- Automation of knowledge discovery is difficult → DM
  hypothesis needed
- Only small amounts of data may be handled (esp. spreadsheets)
  but exploding amount of raw data available

Ref.

Images: WBS excel (2009) | Flickr (cc by 2.0)

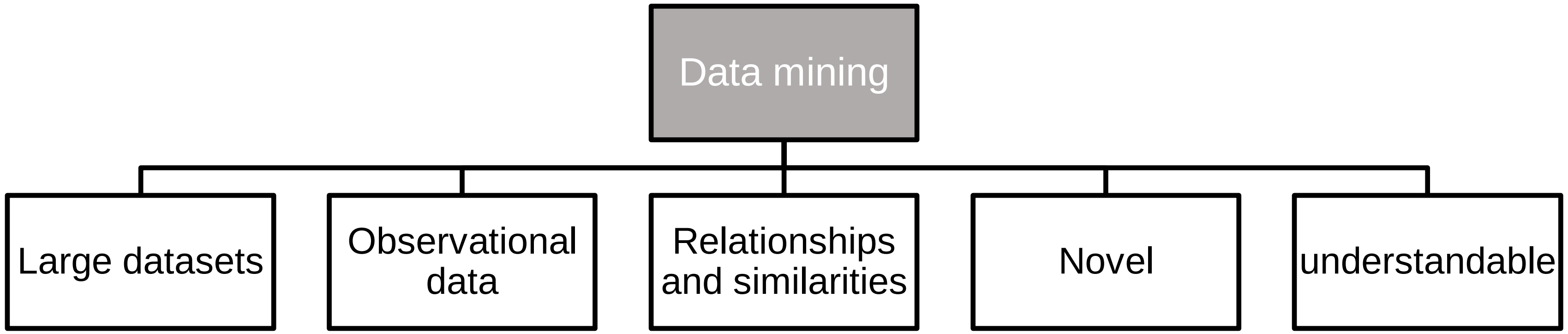
Major roots of data mining

Data Mining

- Business Economics / Marketing
  „business application“ view
  BWL
- Statistics
  „mathematical modeling“ view
  Statistik
- Machine Learning (AI)
  „computational algorithm“ view
- Database systems
  „data processing“ view
  Informatik

Ref.

Data mining: definition (1/3)

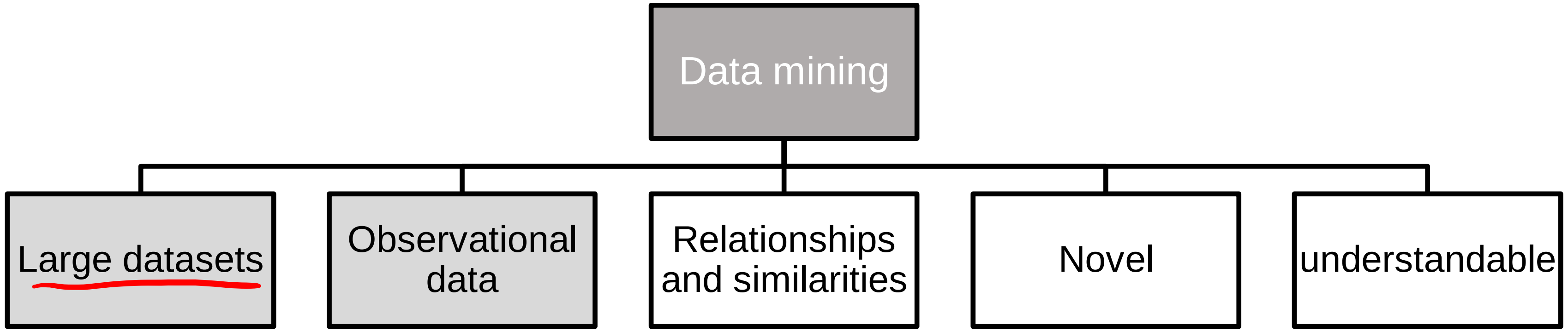


"Data mining is the analysis of (often large) observational data sets to find unsuspected relationships and to summarize the data in novel ways that are both understandable and useful to the data owner."

(Hand, Mannila, Smyth (2001), Principles of Data Mining

Ref.

Data mining: definition (2/3)



Often large datasets:

Small datasets ⇒ exploratory data analysis in statistics

Large datasets (as they exist in DWHs) provoke new problems

- ➢ Storage and access of data
- ➢ Runtime issues
- ➢ Determination of representativeness of data
- ➢ Difficulty to decide whether an apparent relationship is merely a chance occurrence or not

Operationale DB

Observational data:

Data often collected for some other purpose than data mining

Objectives of the data mining exercise play no role in data collection strategy

e.g., DWH data relying on an airline reservation system or a bank account administration system

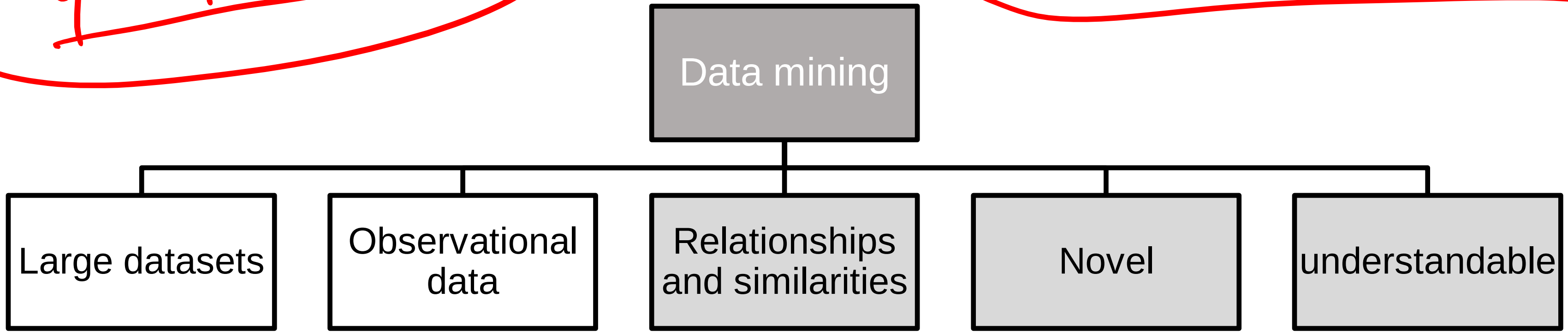
opposite: experimental data (as it is used quite often in statistics)

Ref.

Data mining: definition (3/3)

$y = 1{,}7x + 30$

$p(y > 2{,}05 \wedge x < 80 \mid 0{,}5)$



Gesamt Teilbereich

Relationships and summaries:

often referred to as **models** or **patterns**

e.g., linear equations, tree structures, clusters, patterns in time series, …

Novel:

Novelty should be measured relative to users prior knowledge

Understandable:

Novelty is not sufficient to qualify relationships worth finding

Simple relationships may be preferred to complicated ones

Ref.

Exercise: Data Mining vs. OLAP

Typical questions

Fragestellung	**Data Mining**	**OLAP**
Kundenwert	Welche Kunden bieten uns das größte Deckungsbeitragspotenzial?	Wer waren letztes Jahr unsere 10 besten Kunden?

Kahoot-Fragen
www.kahoot.it
(über Smartphone oder Laptop)
PIN folgt

(Diese Folie ist nach der Vorlesung mit Lösungen verfügbar

Ref.

Fragen?

- Data Mining Introduction
  (will be continued in the next lesson)

Todo for next Week

Support Conny‘s Corner Shop by creating a (or finishing the) simplified Star Scheme (logical model) with tables/relations.
See exercise on slide 23

Ref.

Bibliography

Freie Universität Berlin

- Hand, David J., Heikki Mannila, and Padhraic Smyth. *Principles of data mining*. MIT press, 2001.
- Vaisman, A., & Zimányi, E. (2014). *Data Warehouse Systems*. Springer, Heidelber

Ref.

Recommended reading (for next lessons)

Data Mining

Provost, F. Fawcett, T.	Chapter 2
Berthold et al.	Chapters 1, B, C
Lusti, M.	Data Warehousing und Data Mining (Chapter 6)
Hand, D. et al.:	Principles of Data Mining (esp. Chapters 1, 5, 6 and 11)

Ref.