Part IV

Extraction, Transformation, and Load

Extraction, Transformation, and Load

ETL Process

ETL: Overview

- Two steps
  - From the sources to staging area
    - ★ Extraction of data from the sources
    - ★ Creation / detection of differential updates
    - ★ Creating LOAD Files
  - From the staging area to the base database
    - ★ Data Cleaning and Tagging
    - ★ Preparation of integrated data sets
  - Continuous data provision for the DWH
  - Assurance of consistency regarding DWH data sources
- Efficient methods essential $\rightarrow$ minimize offline time
- Rigorous tests essential $\rightarrow$ ensure data quality

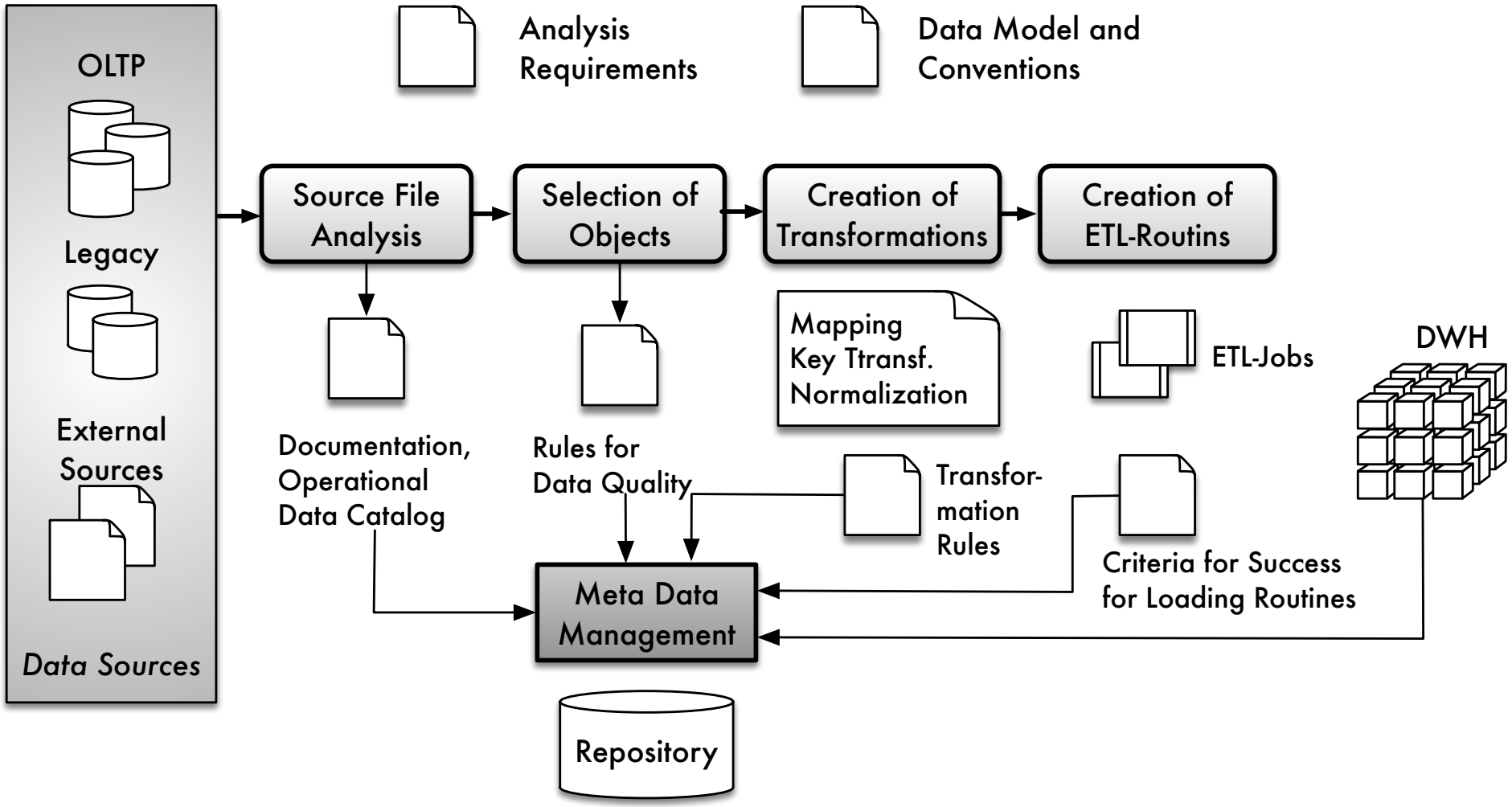
ETL Process

- Frequently most elaborate part of the Data Warehousing
  - Variety of sources
  - Heterogeneity
  - Data volume
  - Complexity of the transformation
    - Schema and instance integration
    - Data cleansing
  - Hardly consistent methods and system support, but variety of tools available

ETL Process

- Extraction: selecting a section of the data from the sources and providing it for transformation
- Transformation: fitting the data to predefined schema and quality requirements
- Load: physical insertion of the data from the staging area into the data warehouse (including necessary aggregations)

Definition Phase of the ETL Process



Extraction of Data from Sources

Extraction

- Task
  - Regular extraction of change data from sources
  - Data provision for the DWH
- Distinction
  - Time of extraction
  - Type of extracted data

Point in Time

- Synchronous notification
  - Source propagates each change
- Asynchronous notification
  - Periodically
    - Sources produce extracts regularly
    - DWH regularly scans dataset
  - Event-driven
    - DWH requests changes before each annual reporting
    - Source informs after each X changes
  - Query-controlled
    - DWH queries for changes before any actual access

Type of Data

- Flow: integrate all changes in DWH
  - Short positions, trade
  - accomodate for changes
- Stock: point in time is essential, must be set
  - Number of employees at end of the month in a store
  - Stock at the end of the year
- Value per Unit: Depending on unit and other dimensions
  - Exchange rate at a point in time
  - Gold price on a stock exchange

Type of Data

- Snapshots: Source always provides complete data set
  - New suppliers directory, new price list, etc.
  - Detect changes
  - Depict history correctly
- Logs: Source provides any change
  - Transaction logs, application-controlled logging
  - Import changes efficiently

Point in Time of Data Provision

Source ...		**Method**	**Timeliness DWH**	**Workload on DWH**	**Worload on Sources**
creates files periodically		Batch runs, Snapshots	depending on frequency	low	low
propagates each change		Trigger, Replication	maximum	high	very high
creates extracts on request	before use	very hard	maximum	medium	medium
	application-driven	application-driven	depending on frequency	depending on frequency	depending on frequency

Point in Time of Data Provision

Comments for three previous options:

- Many systens (Mainframe) not accessible online
- Contradicts idea of DWH: More workload on sources
- Technically not efficiently implementable

Extraction from Legacy Systems

- Very dependent on the application
- Access to host systems without online access
  - Access via BATCH, Report Writer, scheduling
- Data in non-standard databases without APIs
  - Programming in PL-1, COBOL, Natural, IMS ...
- Unclear semantics, double occupancy of fields, speaking keys, missing documentation, domain knowledge only held by few people
- But: Commercial tools available

Differential Snapshot Problem

- Many sources provide only the full dataset
  - Molecular biological data bases
  - Customer lists, employee lists
  - Product catalogues
- Problem
  - Repeated import of all data is inefficient
  - Duplikates need to be detected
- Algorithms to compute Delta-Files
- Hard for very large files

[Labio Garcia-Molina 1996]

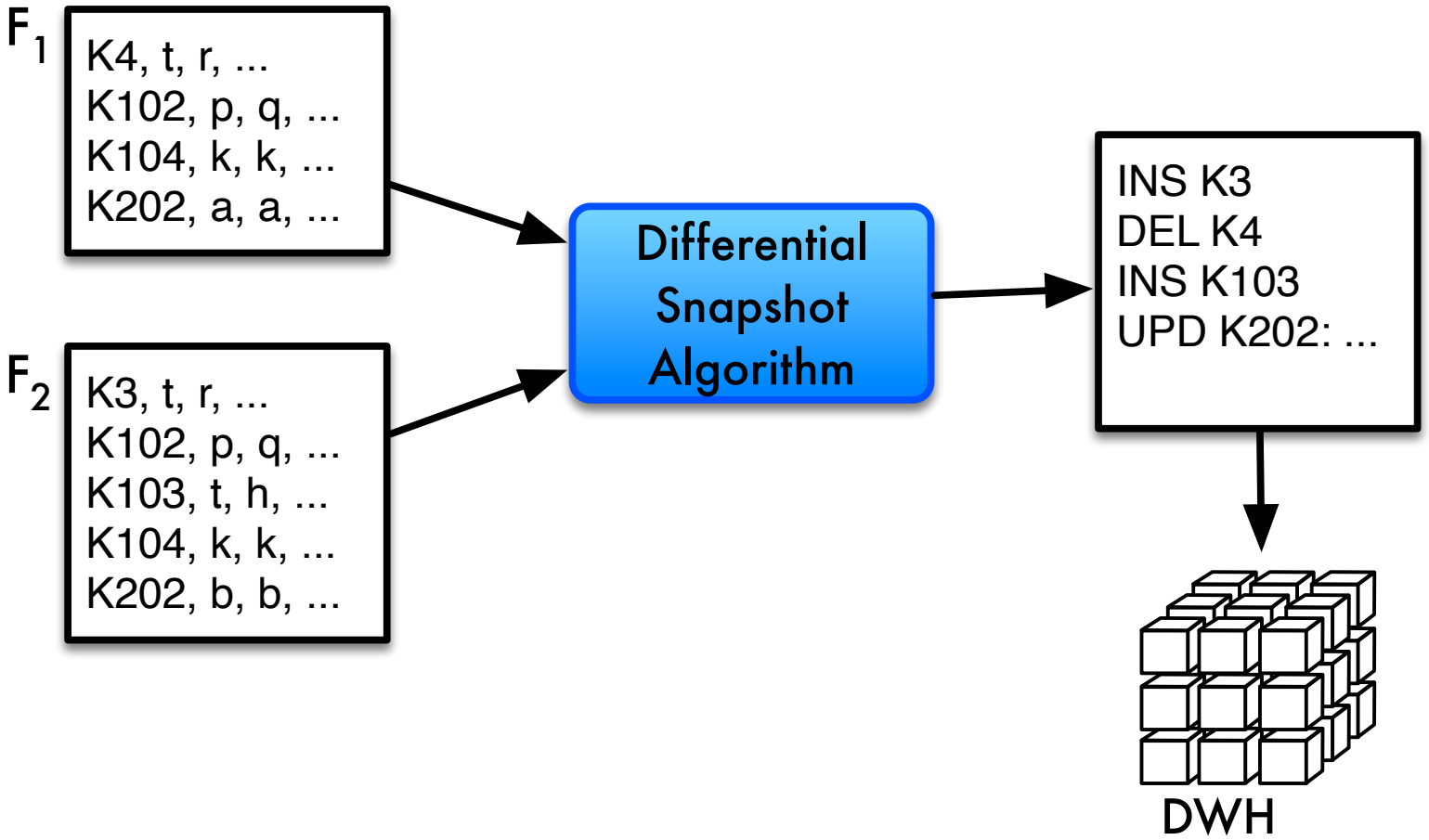
Scenario

- Sources provide Snapshots as file F
  - Unordered set of records $(K, A_1, \ldots, A_n)$
- Given: F_1, F_2, mit $f_1 = |F_1|, f_2 = |F_2|$
- Calculate smallest set $O = \{\texttt{INS}, \texttt{DEL}, \texttt{UPD}\}^*$ with $O(F_1) = F_2$
- O not unique!

$$O_1 = \{(\texttt{INS}(X)), \emptyset, (\texttt{DEL}(X))\} \equiv O_2 = \{\emptyset, \emptyset, \emptyset\}$$

Differential Snapshot Problem

Scenario


F1
K4, t, r, ...
K102, p, q, ...
K104, k, k, ...
K202, a, a, ...
F2
K3, t, r, ...
K102, p, q, ...
K103, t, h, ...
K104, k, k, ...
K202, b, b, ...
Differential Snapshot Algorithm
INS K3
DEL K4
INS K103
UPD K202: ...
DWH

Assumptions

- Computing a consecutive order of DS
  - Files from 1.1.2010, 1.2.2010, 1.3.2010, ...
- Cost Model
  - All operations in the main memory are for free
  - IO counts the number of records: sequential read
  - No consideration of block sizes
- Size of main memory: M (Records)
- File size $|F_x| = f_x$ (Records)
- Files generally larger than main memory

DS_{naive} – Nested Loop

- Computing O
  - Read record R from F_1
  - Read F_2 sequentially and compare to R
    - ★ R not in $F_2 \rightarrow O := O \cup (\texttt{DEL}(R))$
    - ★ R in $F_2 \rightarrow O := O \cup (\texttt{UPD}(R))$ / ignore
- Problem: `INS` is not found
  - Auxiliary structure necessary
  - Array with IDs from F_2 (generated on the fly)
  - Mark R respectively, final run for `INS`
- Number of IO operations: $f_1 \cdot f_2 + \delta$
- Improvements?
  - Cancel search in F_2 if R has been found
  - Load partitions of size M from F_1: $\frac{f_1}{M} \cdot f_2$

DS_{small} – small files

- Assumption: Main memory $M > f_1$ (or f_2)
- Computing O
  - Read F_1 completely
  - Read F_2 sequentially (S)
    - $S \in F_1$: $O := O \cup (\texttt{UPD}(S))$ / ignore
    - $S \notin F_1$: $O := O \cup (\texttt{INS}(S))$
    - Mark S in F_1 (Bitarray)
  - Finally: Records $R \in F_1$ without marks: $O := O \cup (\texttt{DEL}(R))$
- Number of IO operations: $f_1 + f_2 + \delta$
- Improvements
  - Sort F_1 in the main memory $\rightsquigarrow$ faster lookup

DS_{sort} – Sort-Merge

- General case: $M \ll f_1$ und $M \ll f_2$
- Assumption: F_1 is sorted
- Sort F_2 in secondary storage
  - read F_2 in partitions P_i with $|P_i| = M$
  - Sort P_i in main memory and write in F^i ("Runs")
  - Mix all F^i
  - Assumption: $M > \sqrt{|F_2|} \quad \rightarrow$ IO: $4 \cdot f_2$
- Keep sorted F_2 for next DS (becomes F_1 there)
  - Per DS only F_2 needs to be sorted
- Computing O
  - Open sorted F_1 and F_2
  - Mix (parallel reads with skipping)
- Number of IO operations: $f_1 + 5 \cdot f_2 + \delta$

DS_{sort2} – Interleaved

- Sorted F_1 given
- Computing O
  - Read F_2 in partitions P_i with $|P_i| = M$
  - Sort P_i in main memory and write in F_2^i
  - Mix all F_2^i and simultaneously compare to F_1
- Number of IO operations: $f_1 + 4 \cdot f_2 + \delta$

DS_{hash} – Partitioned Hash

- Calculating O
  - Hash F_2 in partitions P_i with $|P_i| = M/2$
  - Hash funktion has to guarantee:

$$P_i \cap P_j = \emptyset, \quad \forall i \neq j$$

  - Partitions are "equivalence classes" w.r.t. the hash function
  - F_1 is still partitioned
  - F_1 and F_2 have been partitioned by the same hash function
  - Read and mix $P_{1,i}$ and $P_{2,i}$ in parallel
- Number of IO operations: $f_1 + 3 \cdot f_2 + \delta$

Why not simply . . .

- UNIX diff?
  - diff requires / considers surroundings of records
  - Here: records are not ordered
- in the database with SQL?
  - Requires to read each relation three times

```
INSERT INTO delta
    SELECT 'UPD', ...FROM F1, F2
    WHERE F1.K = F2.K AND F1.W <> F2.W
UNION
    SELECT 'INS', ...FROM F2
    WHERE NOT EXISTS (...)
UNION
    SELECT 'DEL', ...FROM F1
    WHERE NOT EXISTS (...)
```

Comparison – Features

	IO	**Bemerkungen**
DS_{naive}	$f_1 \cdot f_2$	out of concurrence, auxiliary data structure required
DS_{small}	$f_1 + f_2$	only for smaller files
DS_{sort2}	$f_1 + 4 \cdot f_2$	
DS_{hash}	$f_1 + 3 \cdot f_2$	non-overlapping hash function, hard to estimate partition size, assumptions about distribution (Sampling)

- Extensions of DS_{hash} for "worse" hash functions known

Further DS Approaches

- Number of partitions / runs larger than file descriptors in OS
  - Hierarchical external sorting methods
- Compression: Compress Files
  - Larger partitions / runs
  - Better chance of performing comparisons within the main memory
  - In reality faster (assumptions of the cost model)
- "Windows" Algorithm
  - Assumption: Files have a "fuzzy" order
  - Mixing with Sliding Window over both files
  - Returns many redundant **`INS-DEL`** pairs
  - Number of IO operations: $f_1 + f_2$

DS with Timestamp

- Assumption: Records are $(K, A_1, \ldots, A_n, T)$
- T: Timestamp of the last change
- Creating O
  - Adherence of T_{alt}: Last update ($max\{T\}$ of F_1)
  - Read F_2 sequentially
  - Entries with $T > T_{alt}$ interesting
  - But: **`INS`** or **`UPD`**?
- Another problem: **`DEL`** is not found
- Timestamp spares only attribute comparison

Data Load

Load

- Task
  - Efficient incorporation of external data in DWH
- Critical Point
  - Loading operations may block the entire DWH (Write lock on fact table)
- Aspects:
  - Triggers
  - Integrity constraints
  - Index update
  - Update or Insert?

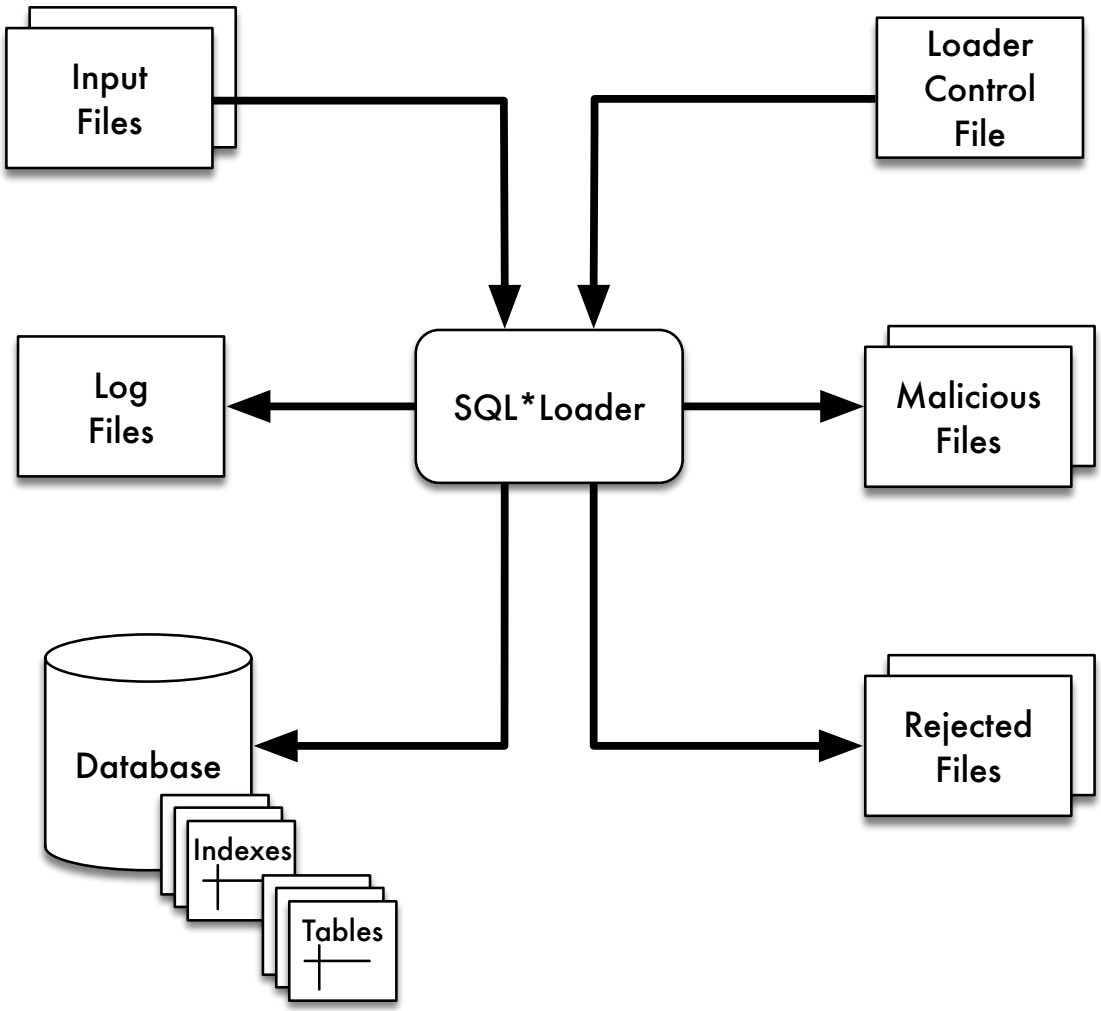
Set based

- Use of standard interfaces:
  PRO*SQL, JDBC, ODBC, ...
- Works in the normal transaction context
- Triggers, indexes and constraints remain active
  - Manual deactivation possible
- No large-scale locks
- Locks can be reduced by `COMMIT`
  - Not in Oracle: Read operations are never locked (MVCC)
- Using prepared statements
- Partial proprietary extensions (arrays) available

BULK Load

- DB-specific extensions for loading large amounts of data
- Running (usually) in a special context
  - Oracle: DIRECTPATH option in the loader
  - Complete table lock
  - No consideration of triggers or constraints
  - Indexes are not updated until after
  - No transactional context
  - No logging
  - Checkpoints for recovery
- Practice: BULK Uploads

Example: ORACLE sqlldr



[Oracle 11g Documentation]

Example: ORACLE sqlldr (2)

- Control-File

```
LOAD DATA
INFILE 'beer.dat'
REPLACE INTO TABLE bevareges (
beer_name POSITION(1) CHAR(35),
beer_price POSITION(37) ZONED(4,2),
beer_bestellgroesse POSITION(42) INTEGER,
bevareges_id "bevareges_seq.nextval"
)
```

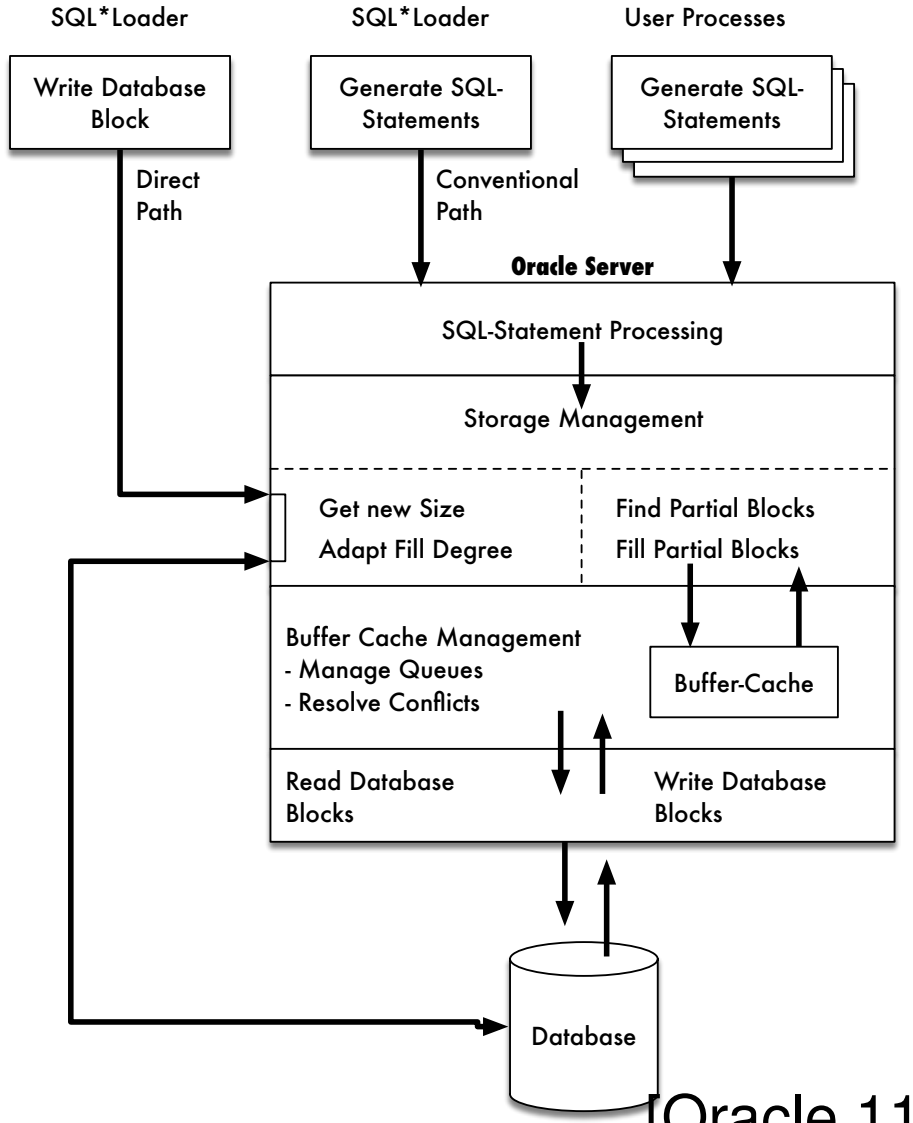
- Data file: *beer.dat*

```
Ilmenauer Pils                    4490 100
Erfurter Bock                     6400 80
Magdeburger Weisse                1290 20
Anhaltinisch Flüssig              8800 200
```

BULK Load Example

- Many options
  - Treatment of exceptions (Badfile)
  - Data transformations
  - Checkpoints
  - Optional fields
  - Conditional loading into multiple tables
  - Conditional loading of records
  - REPLACE or APPEND
  - Parallel load
  - ...

Direct Path Load



[Oracle 11g Documentation]

Multi-Table-Insert in Oracle

- Insert in to multiple tables or multiple times (e.g., for pivoting)

```
INSERT ALL
INTO Quarter_Sales
   VALUES (Product_No, Year || '/Q1', Revenue_Q1)
INTO Quarter_Sales
   VALUES (Product_No, Year || '/Q2', Revenue_Q2)
INTO Quarter_Sales
   VALUES (Product_No, Year || '/Q3', Revenue_Q3)
INTO Quarter_Sales
   VALUES (Product_No, Year || '/Q4', Revenue_Q4)
SELECT ... FROM ...
```

Multi-Table-Insert in Oracle (2)

- Conditional insert

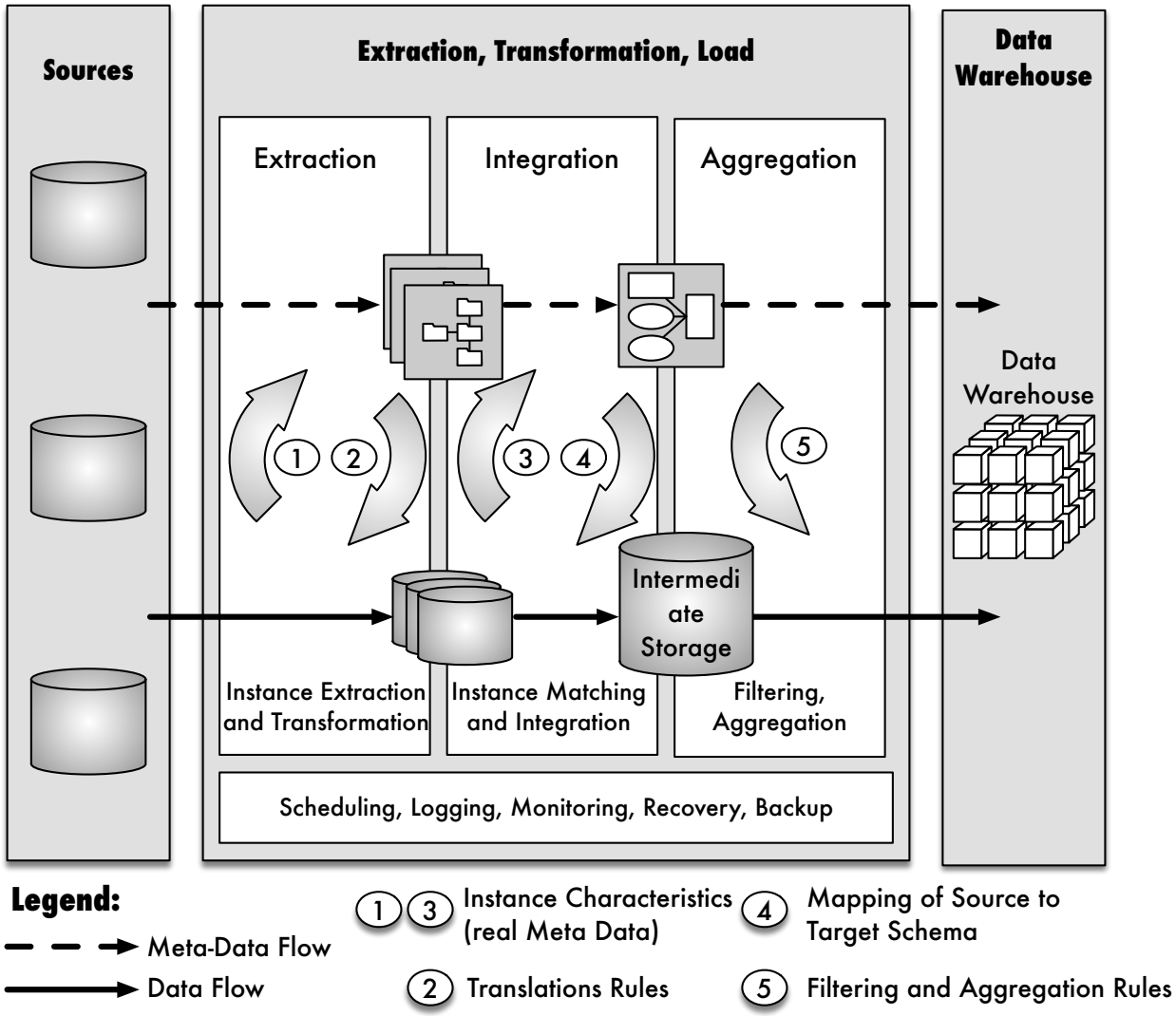
```
INSERT ALL
WHEN ProdNo IN
    (SELECT ProdNo FROM Promotions)
INTO Promotion_Sales
   VALUES (ProdNo, Quarter, Revenue)
WHEN Revenue > 1000
   INTO Top_Products VALUES (ProdNo)
SELECT ... FROM ...
```

Merge in Oracle

- Merge: attempt an insert in error (by breach of a key condition) → Update

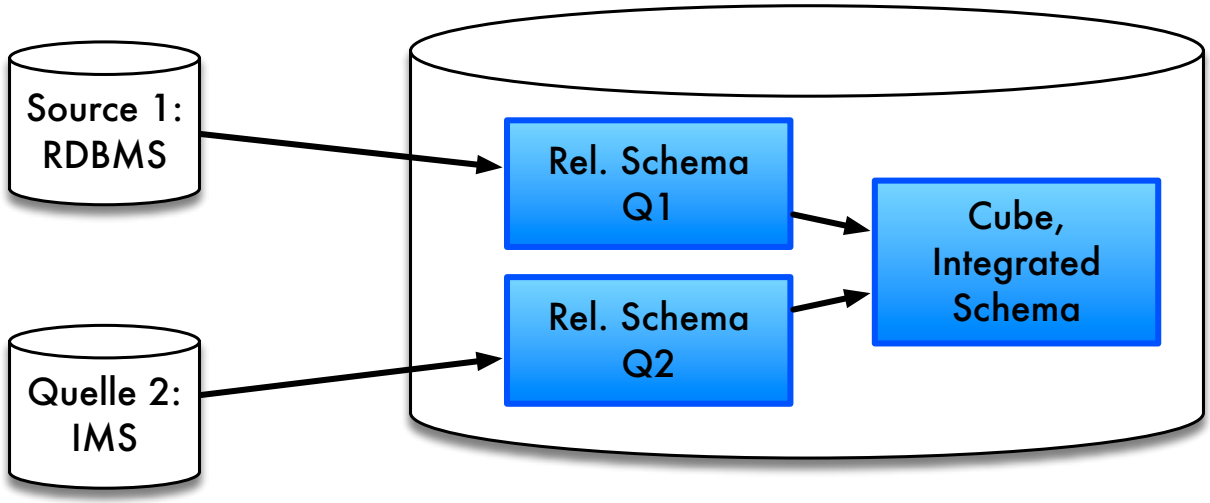
```
MERGE INTO Customer C USING New_Customers N
ON (N.Name = C.Name AND N.BirthDate = C.BirthDate)
WHEN MATCHED THEN
UPDATE SET C.Name = N.Name, C.Fname=N.Fname,
    C.BirthDate=N.BirthDate
WHEN NOT MATCHED THEN
INSERT VALUES (MySeq.NextVal, N.Name,
    N.Fname, N.BirthDate)
```

The ETL Process: Transformation Tasks



[Rahm Do 2000]

Method: Source – Staging Area – CoreDB



- BULK Load only the first step
- Next loads
  - `INSERT INTO ...SELECT ...`
  - Logging can be switched off
  - Parallelizable

Transformation Tasks

- When loading
  - Simple conversions (for LOAD - File)
  - Record orientation (tuples)
  - Preparation for BULK Loader –> mostly scripts or 3GL
- In the data staging area
  - set-oriented calculations
  - Inter-and intra-relation comparison
  - Comparison with core database $\rightarrow$ Duplicates
  - Tagging of records
  - SQL
- Loading in the CoreDB
  - Bulk-Load
  - set-oriented inserts without logging

Task: Source – Staging Area – CoreDB

- What to do, where and when?
  - No defined task assignment

	Extraction **Source → Staging Area**	**Load** **Staging Area → CoreDB**
Access type	record-oriented	set-oriented
Available databases	one source (Updatefile)	many sources
Available datasets	Depending in source: sll, all changes, deltas	CoreDB additionally available
Programming language	Skripts: Perl, AWK, ... or 3GL	SQL, PL/SQL

Transformation Tasks

Transformation

- Problem
  - Data in non-working area not in the format of the core database
  - Structure of the data varies
    - Staging Area: Schema close to source
    - CoreDB: Multidimensional schema
    - Structural heterogeneity
- Aspects
  - Data transformation
  - Schema transformation

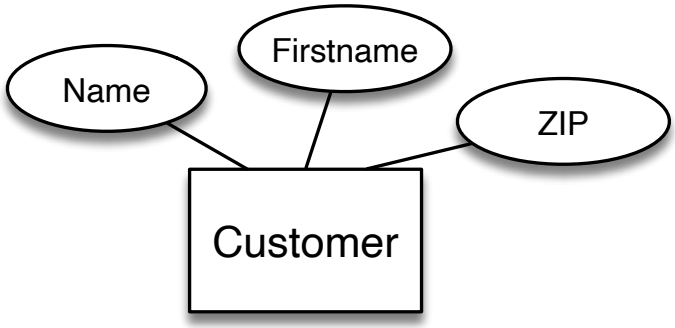
Data and schema heterogeneity

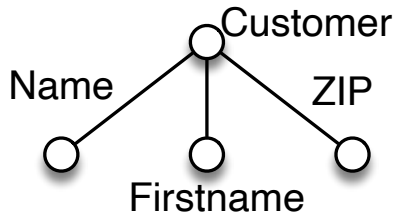
- Main data source: OLTP systems
- Secondary sources:
  - Documents from in-house old archives
  - Documents from the Internet via WWW, FTP
    - ★ Unstructured: access via search engines, . . .
    - ★ Semi Structured: access via search engines, mediators, wrappers etc. as XML documents or similar

Basic problem: heterogeneity of sources

Aspects of Heterogeneity

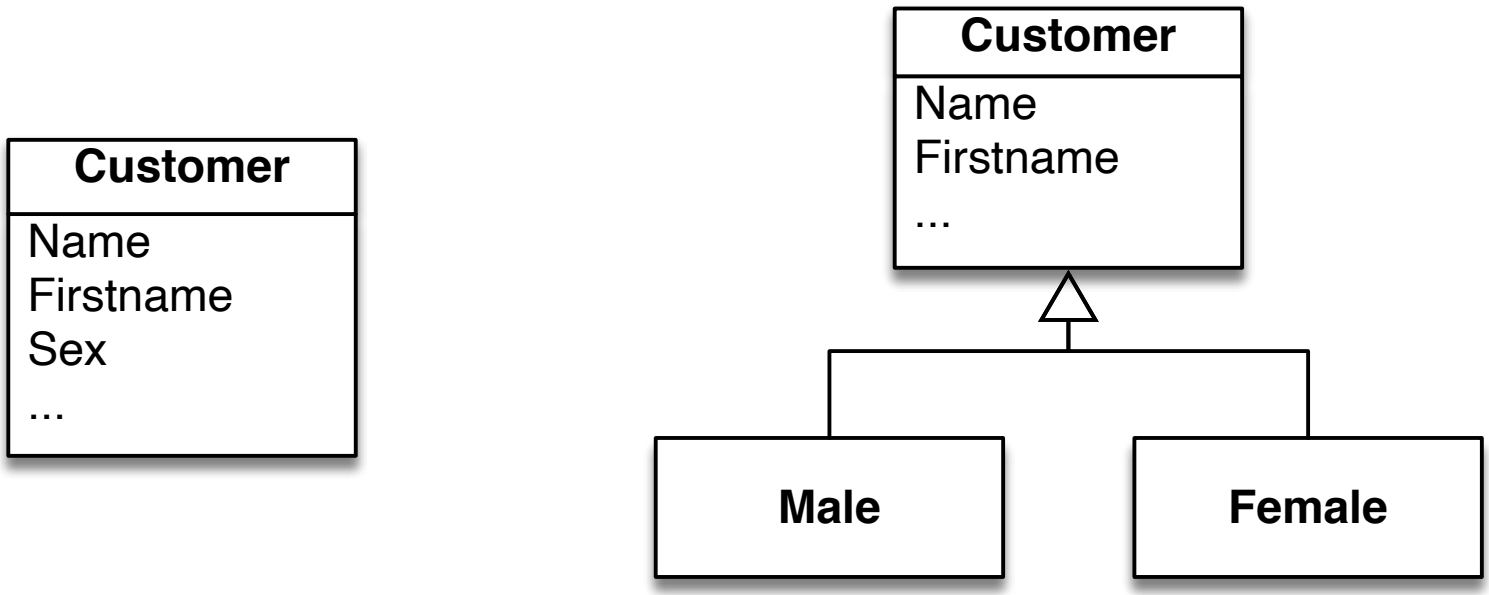
- Various data models
  - Due to autonomous decisions on acquisition of systems in the divisions,
  - Various and different powerful modeling constructs,
  - Application semantics are specifiable in varying degrees Mapping ambiguous between data models
- Example: Relational Model vs. object-oriented modeling vs. XML





Aspects of Heterogeneity (2)

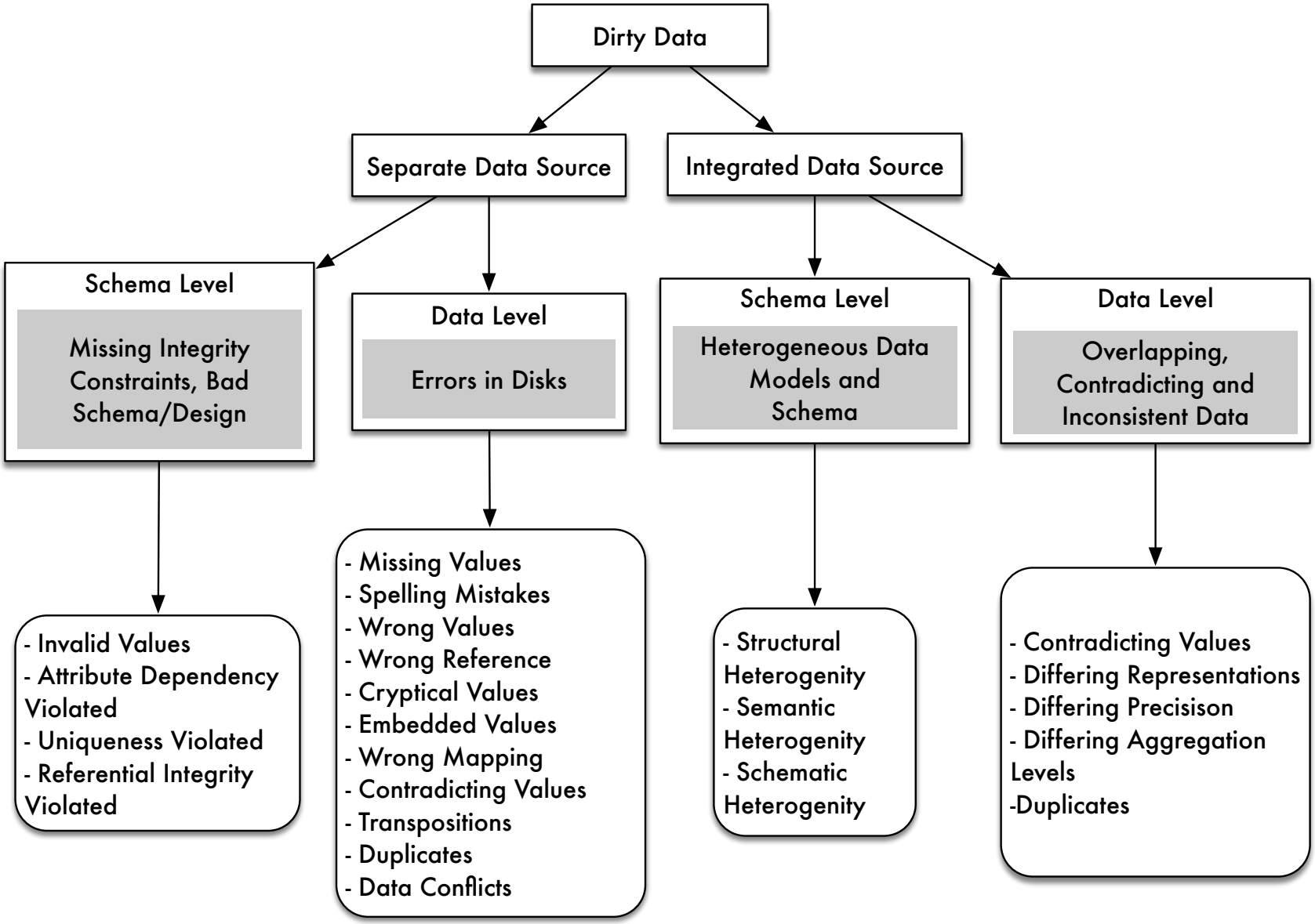
- Different models for the same real-world facts
  - Due to design autonomy
  - Even in the same data model different modeling possible, e.g., by different modeling perspectives of DB Designer



Aspects of Heterogeneity (3)

- Different representations of the data
  - Different data types possible
  - Different scopes of the supported data types
  - Different internal representations of the data
  - Also, different "values" of a data type to represent the same information

Data Error Classification



[Rahm Do 2000, Leser Naumann 2007]

Schema Heterogeneity

Schema Heterogeneity

- Cause: design autonomy $\rightsquigarrow$ different models
  - Different normalization
  - What is a relation, what is an attribute, what is a value?
  - Distribution of data in tables
  - Redundancies from source systems
  - Keys
- In SQL is not well supported
  - INSERT has only one target table
  - SQL accesses data, not schema elements
  - Usually requires programming

Schema Mapping

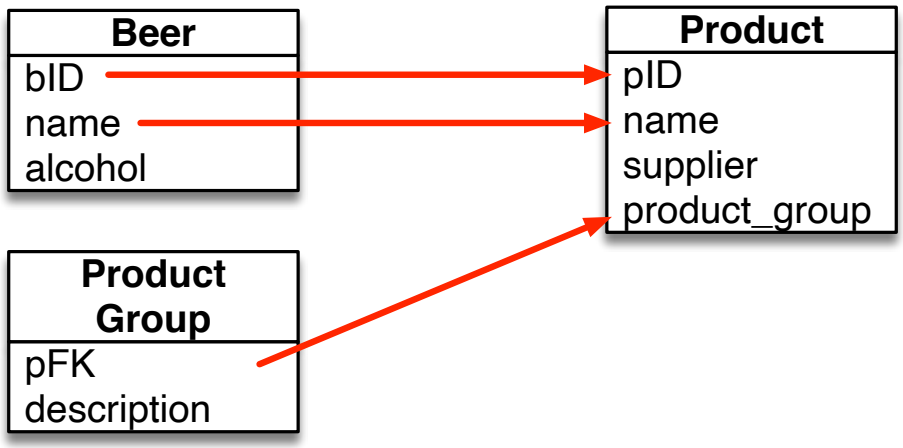
- Data transformation between heterogeneous schemas
  - Old but recurrent problem
  - Usually, experts write complex queries or programs
  - Time intensive
    - Expert for the domain, for schemas and for queries
    - XML makes it even more difficult: XML Schema, XQuery
- Idea: Automation
  - Given: Two schemas and a high-level mapping between them
  - Wanted: query for data transformation

Why is schema mapping difficult?

- Generation of the "right" request, taking into account
  - the source and target schema
  - the mapping
  - and the user intention: semantics!
- Guarantee that the transformed data correspond to the target schema
  - Flat or nested
  - Integrity constraints
- Efficient data transformation

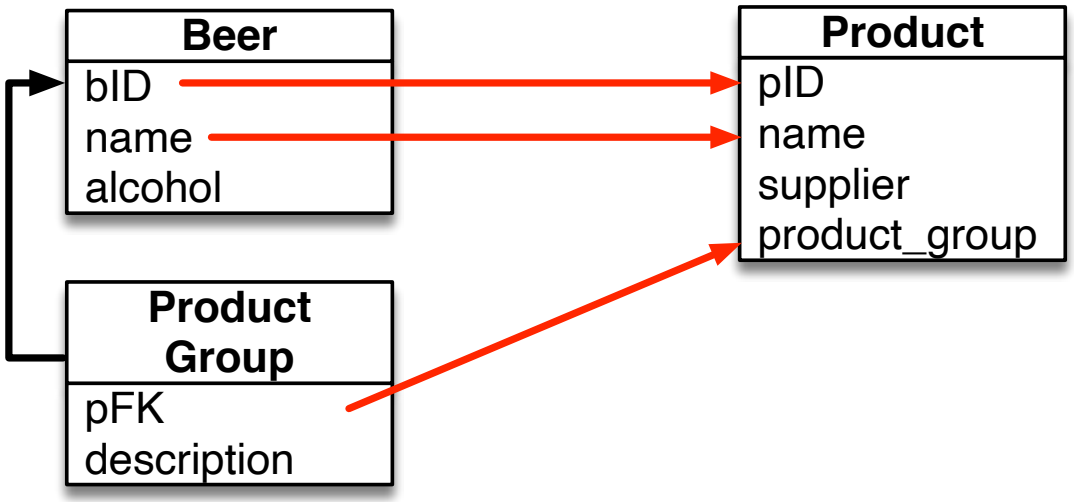
Schema Mapping: Normalized vs. Denormalized

- 1:1 associations are represented differently
  - By occurrence in the same tuple
  - Due to foreign key relationship




```
SELECT bID AS pID, name, NULL AS supplier,
    NULL AS product_group FROM Beer
UNION
SELECT NULL AS pID, NULL AS name, NULL AS supplier,
   description AS product_group FROM Product_group
```

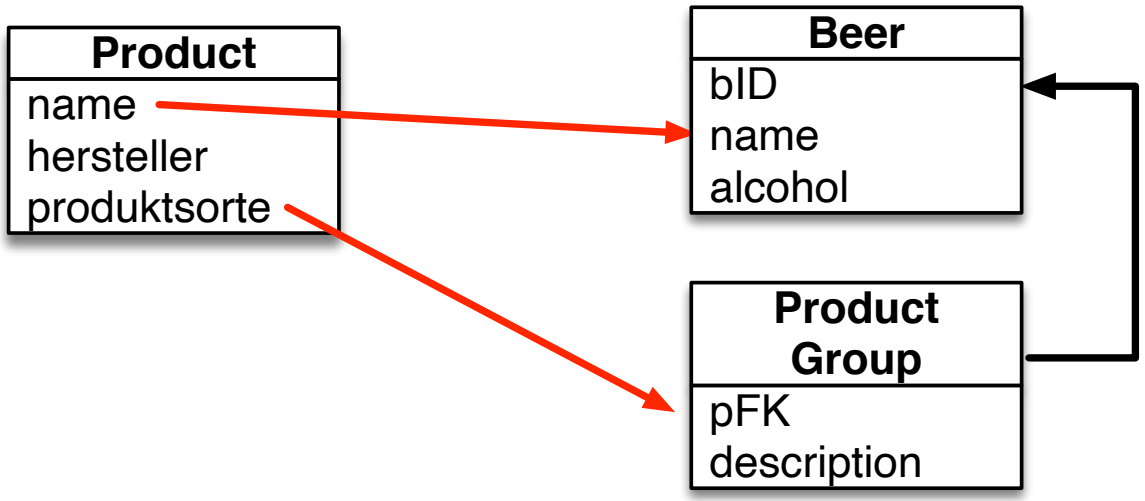
Schema Mapping: Normalized vs. Denormalized (2)




```
SELECT bID AS pID, name, NULL AS supplier,
   description AS product_group
FROM Beer, Product_group
WHERE bID = pFK
```

Only one of four possible interpretations!

Schema Mapping:Normalized vs. Denormalized (3)

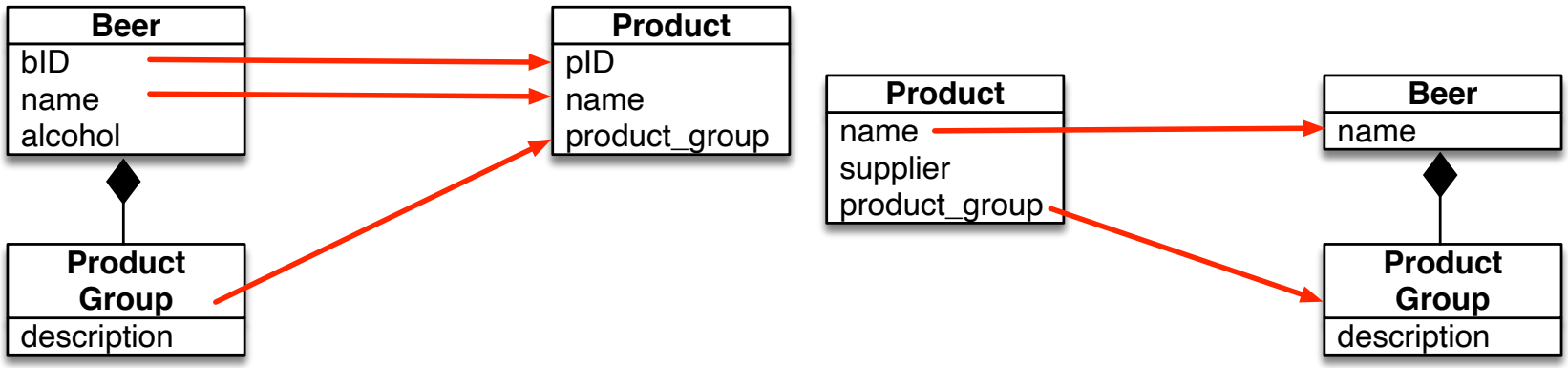


- Requires key generation: Skolem function SK, supplying a unique value with respect to the input (e.g., concatenation of all values)

```
Beer          := SELECT SK(name) AS bID, name,
     NULL AS alcohol FROM Product
Produktsorte := SELECT SK(name) AS pFK,
     product_group AS description FROM Product
```

Schema mapping: Nested vs. Flat

- 1:1 associations are represented differently
  - I.e., nested elements
  - Due to foreign key relationship



Difficulties

- Example: `Source(ID, Name, Street, ZIP, Revenue)`
- Target schema #1

  `Customer(ID, Name, Revenue)`

  `Address(ID, Street, ZIP)`
  - Requires 2 scans of the source table

```
INSERT INTO Customer ... SELECT ...
INSERT INTO Address ... SELECT ...
```

- Target schema #2

  `PremCustomer(ID, Name, Revenue)`

  `NormCustomer(ID, Name, Revenue)`
  - Requires 2 scans of the source table

```
INSERT INTO PremCustomer ... SELECT ...
 WHERE Revenue>=X
INSERT INTO NormCustomer ... SELECT ...
 WHERE Revenue<X
```

Difficulties (2)

- Schema

  `P1(Id, Name, Gender)`

  `P2(Id, Name, M, W)`

  `P31(Id, Name),P32(Id, Name)`

- P1 $\rightarrow$ P2

```
INSERT INTO P2 (id, name, 'T', 'F') ... SELECT ...
INSERT INTO P2 (id, name, 'F', 'T') ... SELECT ...
```

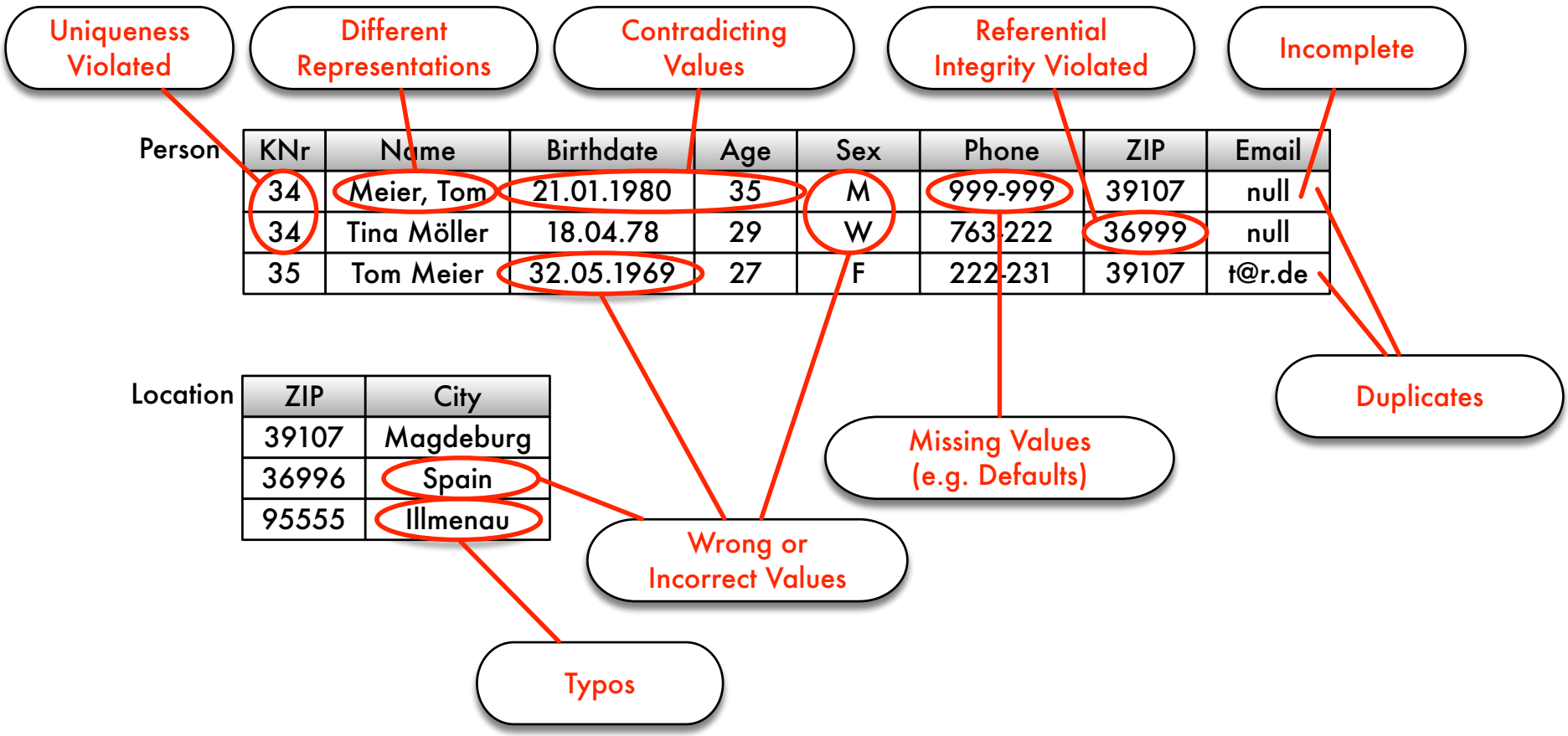
- P3 $\rightarrow$ P1

```
INSERT INTO P1(id, name, 'female') ...
   SELECT ... FROM P31
INSERT INTO P1(id, name, 'male') ...
   SELECT ... FROM P32
```

- Number of values must be fixed; new gender – Change all queries

Data Errors

Data Errors

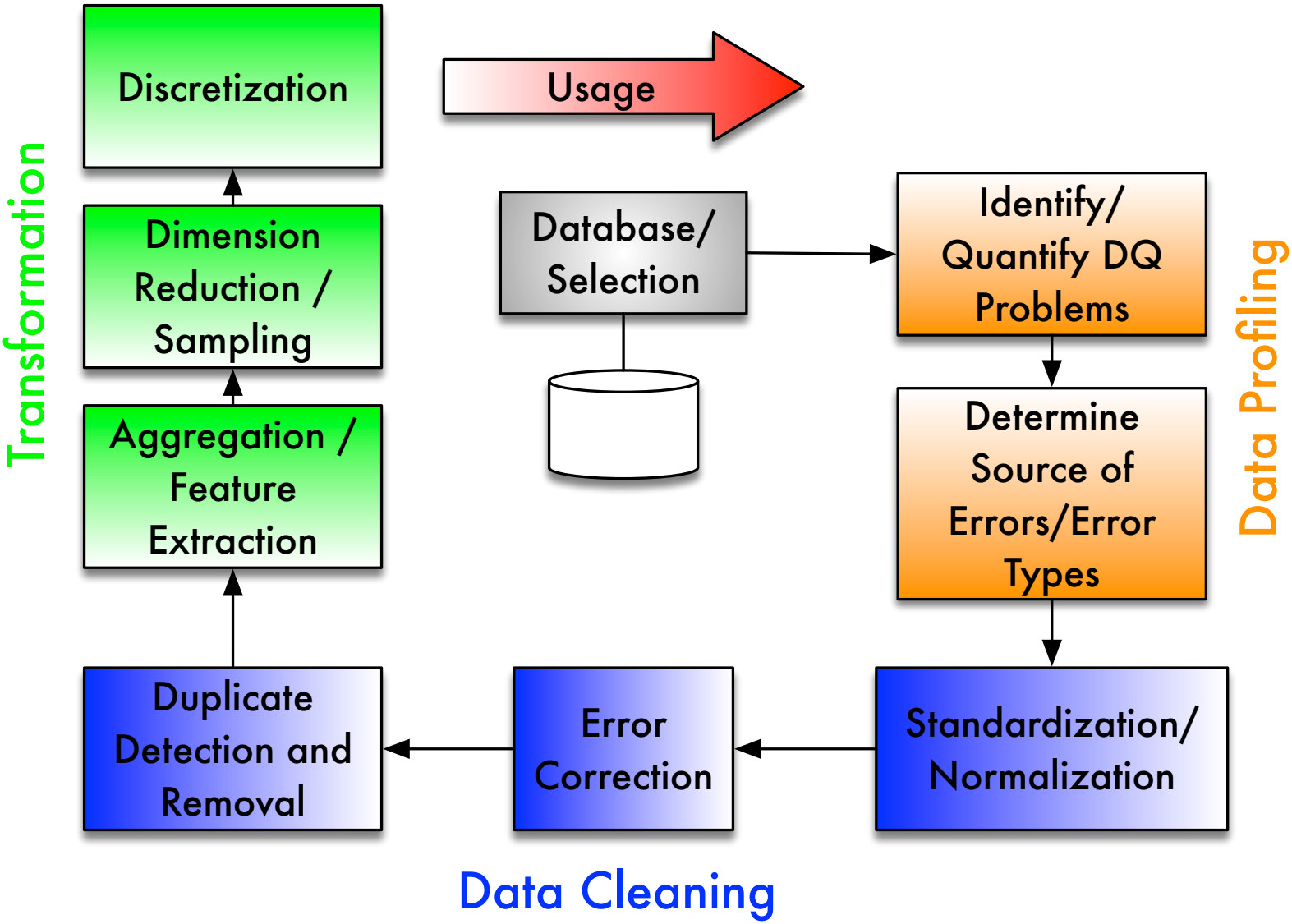

Uniqueness Violated
Different Representations
Contradicting Values
Referential Integrity Violated
Incomplete
Person
KNr | Name | Birthdate | Age | Sex | Phone | ZIP | Email
34 | Meier, Tom | 21.01.1980 | 35 | M | 999-999 | 39107 | null
34 | Tina Möller | 18.04.78 | 29 | W | 763-222 | 36999 | null
35 | Tom Meier | 32.05.1969 | 27 | F | 222-231 | 39107 | t@r.de
Location
ZIP | City
39107 | Magdeburg
36996 | Spain
95555 | Illmenau
Duplicates
Missing Values (e.g. Defaults)
Wrong or Incorrect Values
Typos

Avoiding Data Errors

Avoiding of	**by**
wrong data types	Data type definition, **`domain`**-constraints
wrong values	**`check`**
missing values	**`not null`**
invalid foreign key references	**`foreign key`**
Duplikates	**`unique`**, **`primary key`**
Inkonsistencies	transactions
outdated data	replikation, materialized views

- However, in practice:
  - Lack of metadata and integrity constraints, ...
  - Input errors, ignorance, ...
  - Heterogeneity
  - ...

Phases of Data Processing



Data Profiling

- Analysis of the content and structure of individual attributes
  - Data type, range, distribution and variance, occurrence of null values, uniqueness, pattern (e.g., dd / mm / yyyy)
- Analysis of dependencies between attributes of a relation
  - "fuzzy" keys
  - Functional dependencies, potential primary key, "fuzzy" dependencies
  - Need:
    - ★ No explicit constraints specified
    - ★ However, in most data satisfied
- Analysis of overlaps between attributes of different relations
  - Redundancies, foreign key relationships

Data Profiling (2)

- Missing or incorrect values
  - Calculated vs. Expected cardinality (e.g. number of branches, gender of clients)
  - ANumber of null values, minimum / maximum, variance
- Data or input errors
  - Sorting and manual testing
  - Similarity tests
- Duplicates
  - Number of tuples vs. attribute cardinality

Data Profiling with SQL

- SQL queries for simple profiling tasks
  - Schema, data types: requests to schema catalog
  - Range of values

```
select min(A), max(A), count(distinct A)
from Tabelle
```

  - Data errors, default values

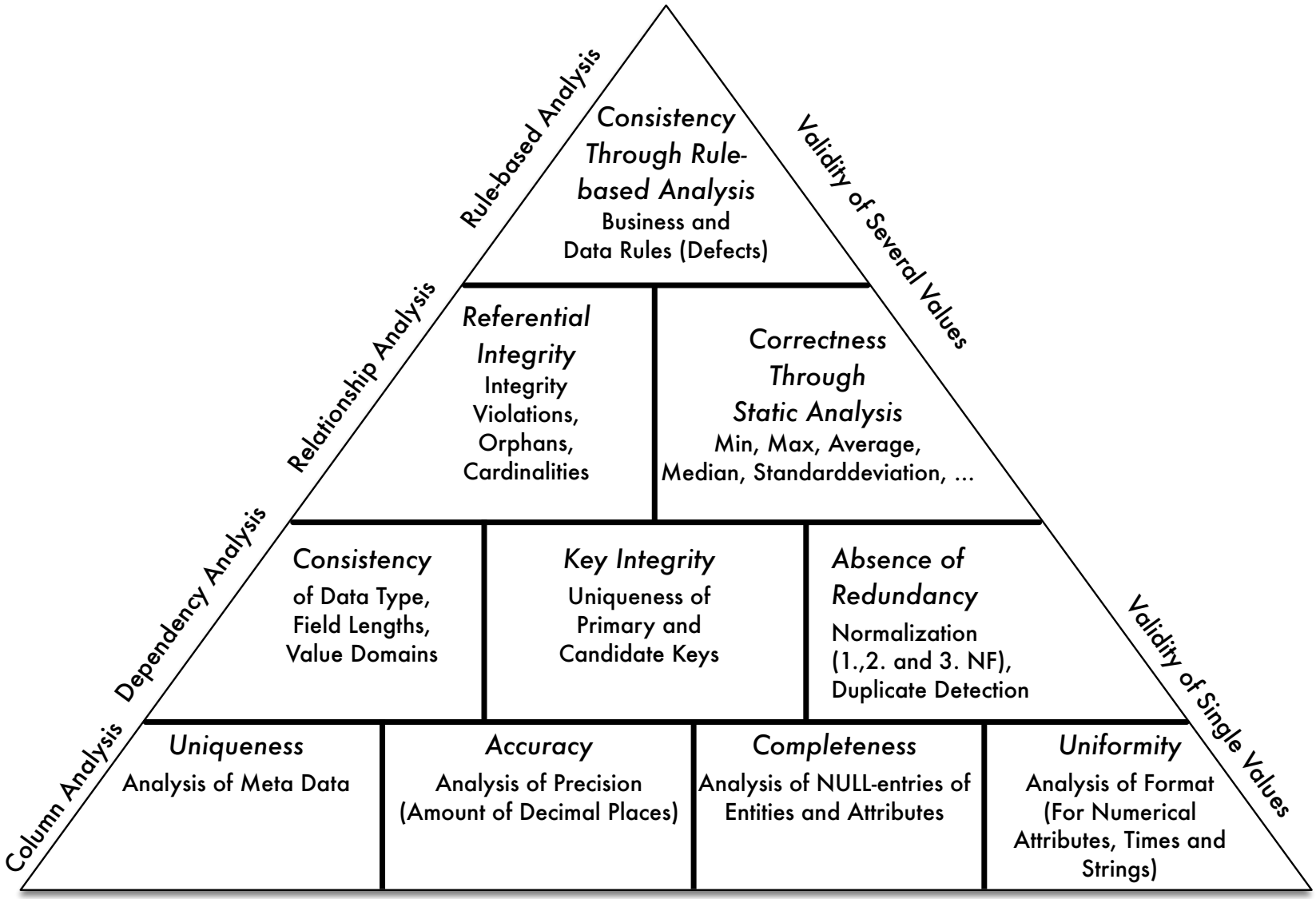
```
select City, count(*) as Numb
from Customer group by City order by Numb
```

    - ★ Ascending: Input errors, e.g., Illmenau: 1, Ilmenau: 50
    - ★ Descending: undocumented default values, z.B. AAA: 80

Data Cleaning

- Detect & eliminate inconsistencies, contradictions, and errors in data with the aim of improving the quality.
- Also Cleansing or Scrubbing
- Up to 80% of the expense in DW projects
- Cleaning in DW: part of the ETL process

Data Quality and Data Cleaning



Normalization and Standardization

- Data type conversion: varchar $\rightarrow$ int
- Encodings: 1: address unknown, 2: old address, 3: current address, 4: addresse of spouse, ...
- Normalization: mapping in unified format
  - Date: 03/01/11 $\rightarrow$ 01. März 2011
  - Currency: \$ $\rightarrow$ €
  - Strings to uppercase
- Tokenization: "Saake, Gunter" $\rightarrow$ "Saake", "Gunter"
- Discretization of numeric values
- Domain-specific transformations
  - Codd, Edgar Frank $\rightarrow$ Edgar Frank Codd
  - Str. $\rightarrow$ Street
  - Addresses from address databases
  - Industry-specific product names

Data Transformation

- In SQL well supported
  - Multiple functions in the language standard
  - SString functions, decoding, conversion date, formulas, system variable, ...
  - Create functions in PL/SQL - use in SQL

- Daten

  "Pause, Lilo" $\Rightarrow$ "Pause", "Lilo"
  "Prehn, Leo" $\Rightarrow$ "Prehn", "Leo"

- SQL

```
INSERT INTO customers (last_name, first_name)
SELECT SubStr(name, 0, inStr(name,',')-1),
   SubStr(name, inStr(name,',')+1)
FROM rawdata;
```

Duplicate Detection

- Identify semantically equivalent data sets, i.e., they represent the same real world object
- See also: Record Linkage, Object Identification, Duplicate Elimination, Merge / Purge
  - Merge: Detect duplicates
  - Purge: selection / calculation of the "best" representative per class.

CustomerNr	Name	Address
3346	Just Vorfan	Hafenstrasse 12
3346	Justin Forfun	Hafenstr. 12
5252	Lilo Pause	Kuhweg 42
5268	Lisa Pause	Kuhweg 42
$\perp$	Ann Joy	Domplatz 2a
$\perp$	Anne Scheu	Domplatz 28

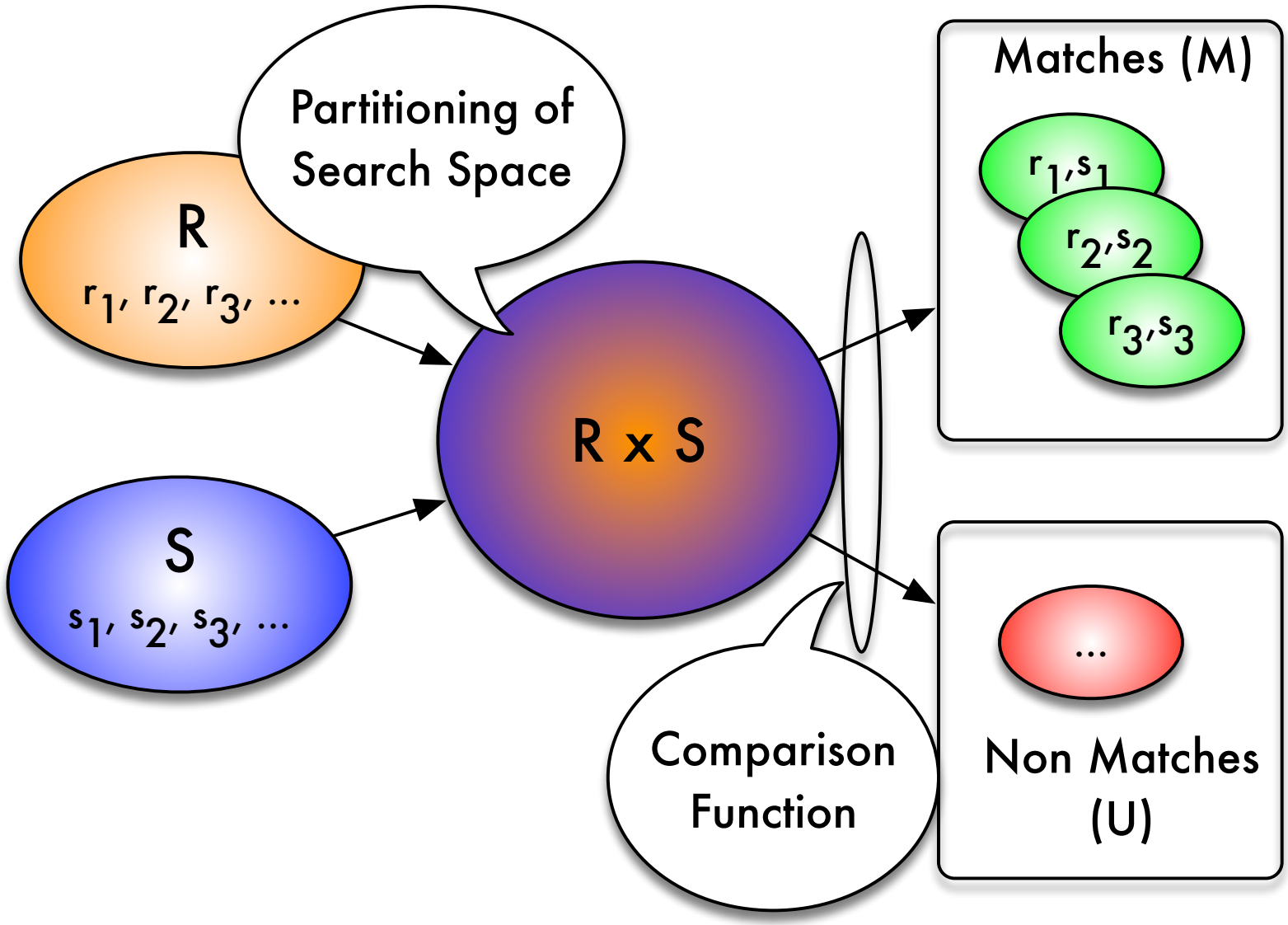
Duplicate Detection: Comparisons

- Typical comparison rules

```
if ssn1 = ssn2 then match
else if name1=name2 then
    if firstname1=firstname2 then
        if adr1=adr2 then match
        else unmatch
    else if adr1=adr2 then match_household
else if adr1=adr2 then
...
```

- Naive approach: "all-vs-all"
  - $O(n^2)$ comparisons
  - Maximum accuracy (depending on rules)
  - Far too expensive

Duplicate Detection: Principle

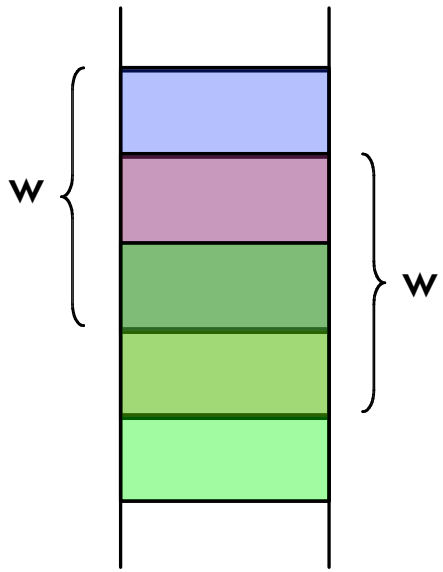


Partitioning

- Blocking
  - Division of the search space into disjoint blocks
  - Duplicates only within a block
- Sorted neighborhood [Hernandez Stolfo 1998]
  - Sorting the data based on a selected key
  - Compare in a sliding window
- Multi-pass technique
  - Transitive closure over different collations

Sorted Neighborhood

1. Compute a key for each record
   - ex: SSN + "first 3 characters of Name" + ...
   - Observance of typical errors: 0-O, Soundex, neighboring keys, ...
2. Sort by key
3. Scan list sequentially
4. Comparisons within a window W, $|W| = w$
   - Which tuples really need to be compared?



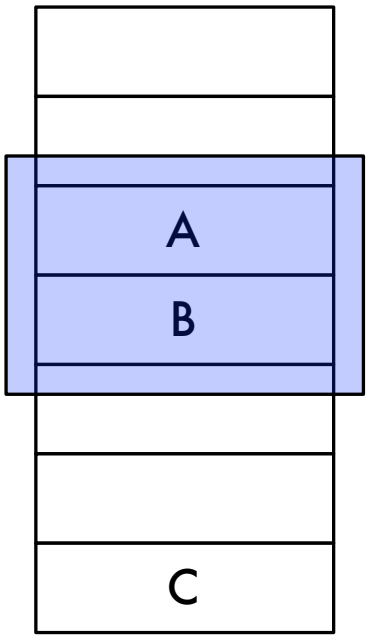
- Complexity
  - Key generation: $O(n)$, sorting: $O(n \cdot \log(n))$; comparing: $O((n/w) \cdot (w^2)) = O(n \cdot w)$;
  - Total: $O(n \cdot \log(n))$ or $O(n \cdot w)$

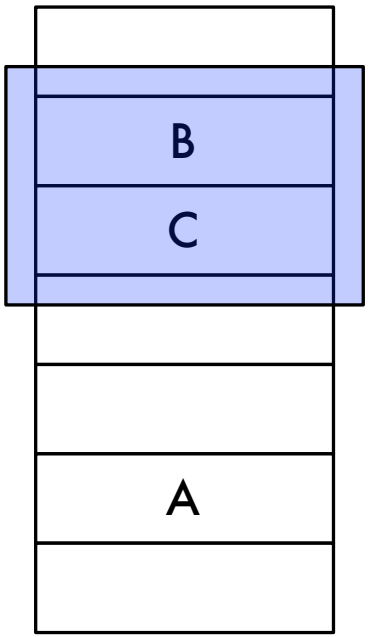
Sorted Neighborhood: Problems

- Poor Accuracy
  - Sorting criterion always prefers certain attributes
  - Are the first letters more important for identity than the last ones?
  - Is Surname more important than the house number?
- Increase window size?
  - Not helpful
  - Dominance of an attribute remains the same, but runtime deteriorates rapidly

Multi-pass technique

- Sort by multiple criteria and identification of duplicates
- Formation of the transitive closure of the duplicates up to a given length





- 1. Run: "A matches B"
- 2. Run: "B matches C"
- Transitivity: "A matches C"

Comparison functions

- Comparison functions for fields (String A und B), including:
  - EEdit distance: number of edit operations (insert, delete, Change) for change from A to B
  - q-Grams: Comparison of the amounts of all substrings of A and B of length q
  - Jaro distance and Jaro-Winkler distance: Consideration of common characters (within the half string length) and transposed characters (at another position)

Edit Distance

- Levensthein Distance:
  - Number of edit operations (insert, delete, modify) for change from A to B
  - Example:

```
edit_distance("Qualität", "Quantität") = 2
   ⇒ update(3,'n')
   ⇒ insert(4,'t')
```

  - Application:

```
select P1.Name, P2.Name
from Produkt P1, Produkt P2
where edit_distance(P1.Name, P2.Name) <= 2
```

q-Grams

- Set of all substrings of length q
  Qualität$_3$:= { __Q, _Qu, Qua, ual, ali, lit, itä, tät, ät_, t__ }
- Observation: strings with small edit distance have many common q-grams, i.e., for edit distance k min.

$$\max(|A|, |B|) - 1 - (k-1) \cdot q$$

  common q-grams
- Positional q-grams: extension with position in a string
  Qualität := { (-1, __Q), (0, _Qu), (1, Qua), ... }
  - Filtering for efficient comparison:
    - ★ COUNT: number of common q-grams
    - ★ POSITION:Position difference between corresponding q-grams $\leq$ k
    - ★ LENGTH: The difference in string lengths $\leq$ k

Data Conflicts

- Data conflict: Two duplicates have different attribute values for a semantically same attribute
  - In contrast to conflicts with integrity constraints
- Data conflicts arise
  - Within an information system (intra-source) and
  - With the integration of multiple information systems (inter-source)
- Prerequisite: Duplicate, already established that identity
- Requires: Conflict Resolution (Purging, Reconciliation)

Data Conflicts: Origins

- Lack of integrity constraints or consistency checks
- In case of redundant schemas
- By partial information
- With emergence of duplicates
- Incorrect entries
  - Typing errors, transmission errors
  - Incorrect calculation results
- Obsolete entries
  - Different update times
    - Adequate timeliness of a source
    - Delayed update
  - Forgotten update

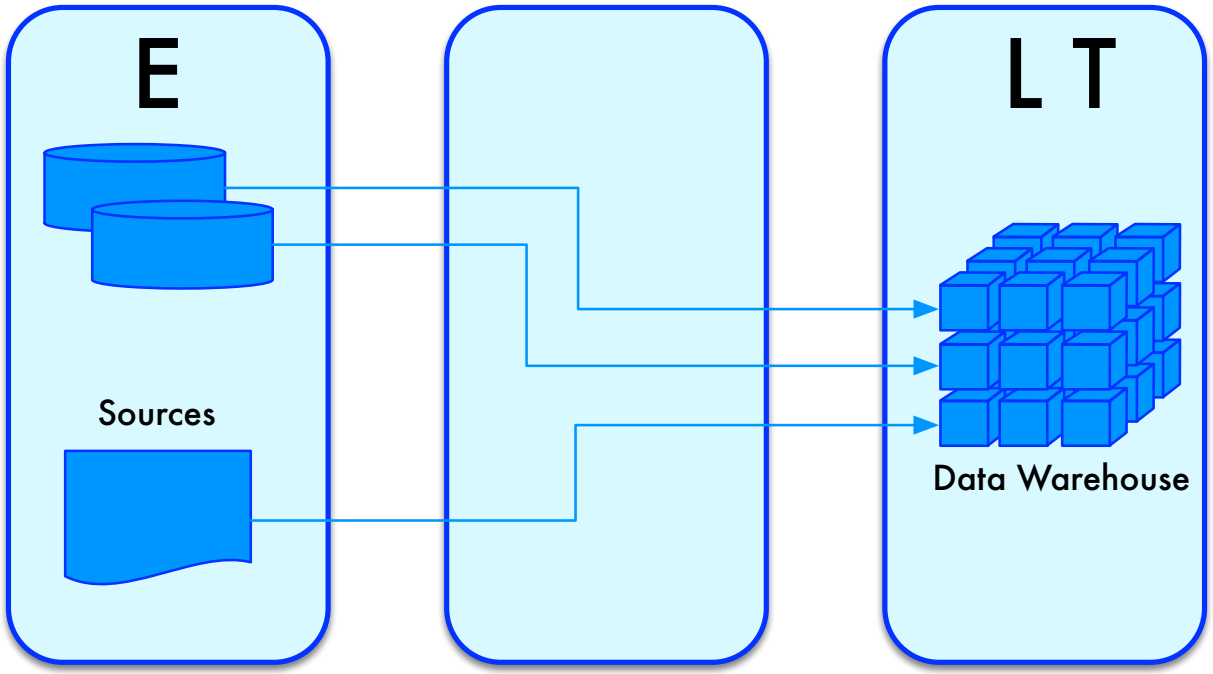
Data Conflicts: Remedies

- Reference tables for exact value mapping
  - For example, cities, countries, product names, codes...
- Similarity measures
  - With typos, language variants (Meier, Mayer, ...)
- Standardizing and transforming
- Use of background knowledge (metadata)
  - For example, conventions (typical spellings)
  - Ontologies, thesauri, dictionaries for the treatment of homonyms, synonyms,. . .
- At integration
  - Preference ordering over data sources according to relevance, trust, opening times, etc.
  - Conflict resolution functions

ELT

ETL vs. ELT

- ELT = Extract-Load-Transform
  - Variant of the ETL process, in which the data is transformed after the load
  - Objective: transformation with SQL statements in the target database
  - Waiving special ETL engines



ELT

- Extraction
  - For Database optimized queries (e.g. SQL)
  - Extraction also monitored with monitors
  - Automatic extraction difficult (e.g. data structure changes)
- Laden
  - Parallel processing of SQL statements
  - Bulk Load (assumption: no write access to the target system)
  - No record-based logging
- Transformation
  - Utilization of set operations of the DW-transformation component
  - Complex transformations by means of procedural languages (e.g., PL/SQL)
  - Specific statements (e.g., CTAS von Oracle)

Summary

- ETL as a process of transferring data from source systems in the DWH
- Topics of ETL and data quality typically make up 80% of efforts in DWH projects!
  - Slow queries are annoying
  - Incorrect results make the DWH useless
- Part of the transformation step
  - Schema level: Schema mapping and schema transformation
  - Instance level: data cleaning