Part II

Data-Warehouse Architecture

Data-Warehouse Architecture

Requirements

Requirements of the Data Warehousing

- Independence between data sources and analytical systems (w.r.t. availability, load, ongoing changes)
- Continuous provision of integrated and derived data (Persistence)
- Reusability of provided data
- Possibility to conduct arbitrary evaluations
- Support of custom views (e.g., w.r.t. time horizon, domain and structure)
- Extensibility (e.g., Integration of new sources)
- Automation of processes
- Uniqueness of data structures, access rights and processes
- Orientation on the main purpose: data analysis

12 OLAP rules by Codd

- Multidimensional, conceptual view
- Transparency
- Accessibility
- Performance
- Scalability
- Generic Dimensionality
- Dynamic handling of sparse multidimensional structures
- Multi-user mode
- Unrestricted operations
- Intuitive user interface
- Flexible reporting
- Any number of dimensionens und aggregation levels

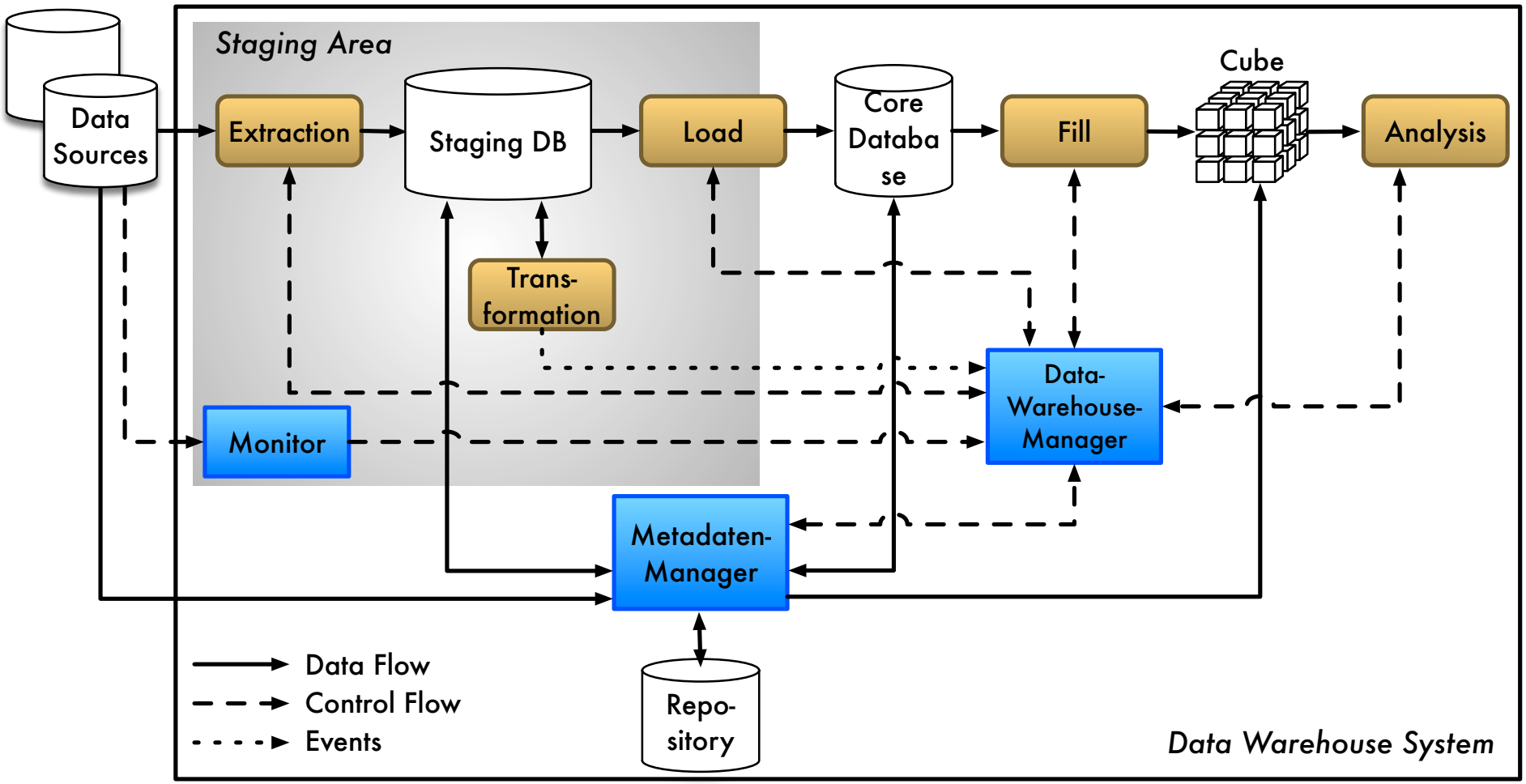
FASMI

Fast Analysis on Shared Multidimensional Information

- Short response times (on average less than five seconds)
- Simple and flexible ways of evaluation
- Heterogeneous users with different rights
- Multidimensionality is an important criterion
- Questions on the number of required dimensions and ranges of values of associated attributes

Reference Architecture

Reference Architecture



Phases of the Data Warehousing

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1. Controlling the sources for changes by using monitors
2. Copying relevant data by extraction into the staging area
3. Transformation of the data in the staging area (cleansing, integration)
4. Copying of the data in an integrated database as the foundation base for various analyzes
5. Filling the data cubes (databases for analysis purposes)
6. Analysis: operations on data of the DW

Basic database and data cubes represent the data warehouse.

Components

Data Warehouse Manager

- Central component of a DW system
- Initiation, control and monitoring of the individual processes (flow control).
- Initiation of the data collection process
  - At regular time intervals (every night, on weekends, etc.): Starting of the data extraction from sources and transferring to the staging area
  - For a change in a source: starting of the respective extraction component
  - On explicit request of the administrator
  - Push vs. Pull strategy
  - Timeliness is a requirement for analytical tasks

Data Warehouse Manager

- After triggering the loading process:
  - Monitoring of the further steps (cleansing, integration, etc.)
  - Coordination of the processing order
- Event of a fault
  - Documentation of errors
  - Restart mechanisms
- Access to metadata from the repository
  - Controlling the flow
  - Parameters of the components

Data sources

- Suppliers of data for the data warehouse
  - Do not belong directly to the DW
  - Can be internal (company) or external (e.g., state institution)
  - Heterogeneous with respect to the structure, content and interfaces (databases, files)
  - Selection of sources and quality of the data of particular importance
- Factors for selection
  - Purpose of the DW
  - Quality of the source data
  - Availability (legal, social, technical)
  - Price for data acquisition (especially for external sources)

Data sources: classification

- Origin: internal, external
- Time: current, historical
- Use level: primary data, meta data
- Content: number, string, graphic, reference, document
- Display: numeric, alpha-numeric, BLOB
- Language and character set
- Degree of confidentiality

Data sources: quality requirements

- Consistency (absence of contradictions),
- Correctness (matching reality),
- Completeness (e.g., the absence of missing values or attributes),
- Reliability (e.g., confidence in the data sources),
- Accuracy (e.g., number of decimal places),
- Granularity (e.g., daily or monthly data),
- Timeliness (When was the last change performed vs. the occurence of the data change),
- Relevance (How important is the data?),
- ...

Data sources: quality requirements (2)

- Reliability (traceability of the origin, trustworthiness of the supplier),
- Understandability (content-wise and technical / structural for the respective target group),
- Usability (suitable format, expedience),
- Uniformity (data format),
- Intellegibility (interpretability) and
- Key integrity (keys and references)

Monitors

- Task:
  - Discovery of data manipulations in a data source
- Strategies:
  - Trigger-based
    - ★ Active data base mechanisms
      → Activation of triggers due to data changes
      → Copy the modified tuple in another area
  - Replication-based
    - ★ Use of replication mechanisms for the transmission of changed data

Monitors (2)

- Strategies (contd.):
  - Log-based
    - Analysis of transaction log data of the DBMS to detect changes
  - Timestamp-based
    - Assigning a timestamp to tuples
    - Update in case of changes
    - Identification of changes since the last extraction by time comparison
  - Snapshot-based
    - Periodic copy of the dataset in a file (snapshot)
    - Comparison of snapshots to identify changes

Staging DB

- Task:
  - Central data management component for data cleaning
  - Temporary buffer for integration
- Use:
  - Execution of transformations (cleaning, integration, etc.) directly in the intermediate storage
  - Loading of transformed data into DW or core database only after successful completion of the transformation
- Advantages:
  - No influence on the sources or the DW
  - No acceptance of erroneous data

Extraction component

- Task: Transfer data from sources in the data staging area
- Function: dependent on the monitoring strategy
  - Periodically
  - On request
  - Event-controlled (e.g., when reaching a defined number of changes)
  - Immediate extraction
- Implementation:
  - Use of standard interfaces (e.g., ODBC, JDBC)
  - Exception handling in case of an error

Transformation component

- Preparation and adjustment of the data to load
  - Content-wise: data / instance integration and cleaning
  - Structural: schema integration
- Transferring all data in a uniform format
  - Data types,
  - Dates,
  - Units,
  - Encodings, etc.
- Removal of impurities (Data Cleaning or Data Cleansing)
  - Incorrect or missing values,
  - Redundancies,
  - Outdated values.

Transformations component (2)

- Data Scrubbing:
  - Utilization of domain-specific knowledge (e.g. business rules) to detect impurities
  - Example: detection of redundancies
- Data Auditing:
  - Application of data mining methods to uncover rules
  - Detection of deviations

Loading component

- Task:
  - Transfer of the adjusted and processed (e.g., aggreated) data to the core database or the DW
- Features:
  - Use of special loading tools (e.g, SQL*Loader by Oracle)
    $\rightarrow$ Bulk loading
  - Historicization: Changes in sources may not overwrite DW data, instead they are stored in addition
- Loading process:
  - Online: Core database or DW is still available
  - Offline: not available (time window: at night, during weekends)

Core database

- Task:
  - Integrated database for various analyses
    $\rightarrow$ independent of specific analyses, i.e., no aggregations yet
  - Supply of the DW with adjusted data (possibly by compression)
- Notes:
  - Often ommitted in practice
  - Equivalent to Operational Data Store (ODS) by Inmon

Data Cube

- Task: databases for analysis purposes (relational or multi-dimensional)
- Structure based on analysis needs
- Basis: DBMS
- Features:
  - Support the load process
    - ★ Fast loading of large amounts of data
      $\rightarrow$ Bulk loader, bypassing multi-user coordination and consistency checks
  - Support of the analysis process
    - ★ Efficient query processing (index structures, caching)
    - ★ Multidimensional data model (e.g., via OLE DB for OLAP)

Data Warehouse

In a narrower sense:
Core database and data cubes represent the data warehouse.

- In a broader sense, the data marts also provide components of the data warehouse.

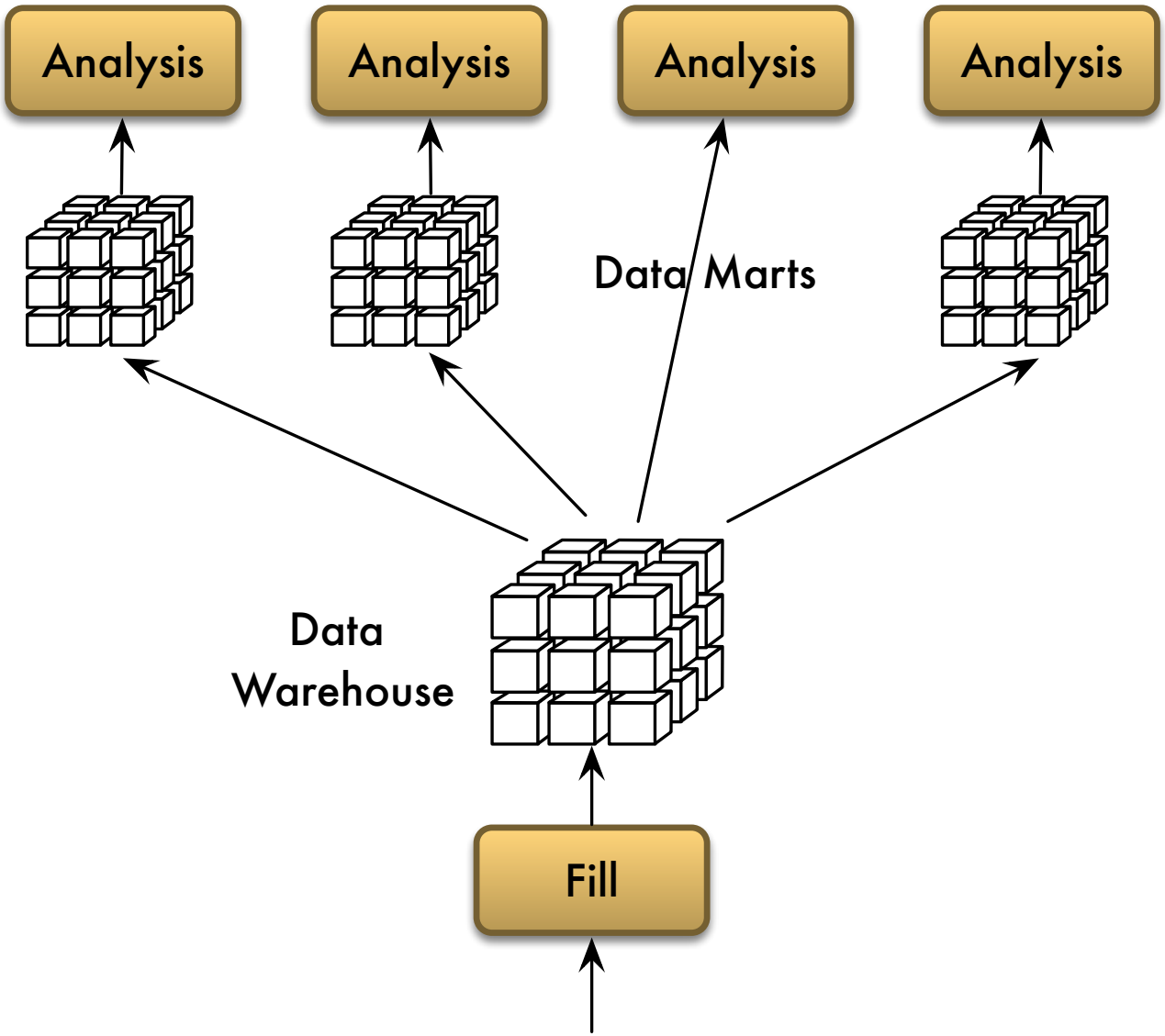
Data Marts

- Task:
  - Providing a content-restricted view of the DW (e.g., Department)
- Reasons:
  - Autonomy, privacy, load balancing, data volume, etc.
- Implementation:
  - Distribution of the DW data
- Forms:
  - Dependent data marts
  - Independent data marts

Dependent Data Marts

- Distribution of the data set after
  - Integration and cleanup (core database) and
  - Organization in accordance with the analysis needs (data cube)
- "Hub and Spoke" architecture
- Data Mart:
  - Only excerpt (including aggregation) of the Data Warehouse
  - No adjustment or normalization
- Analyses on data mart consistent with analyses on DW
- Simple implementation:
  - Replication or view mechanisms of DBMS

"Hub and Spoke" architecture



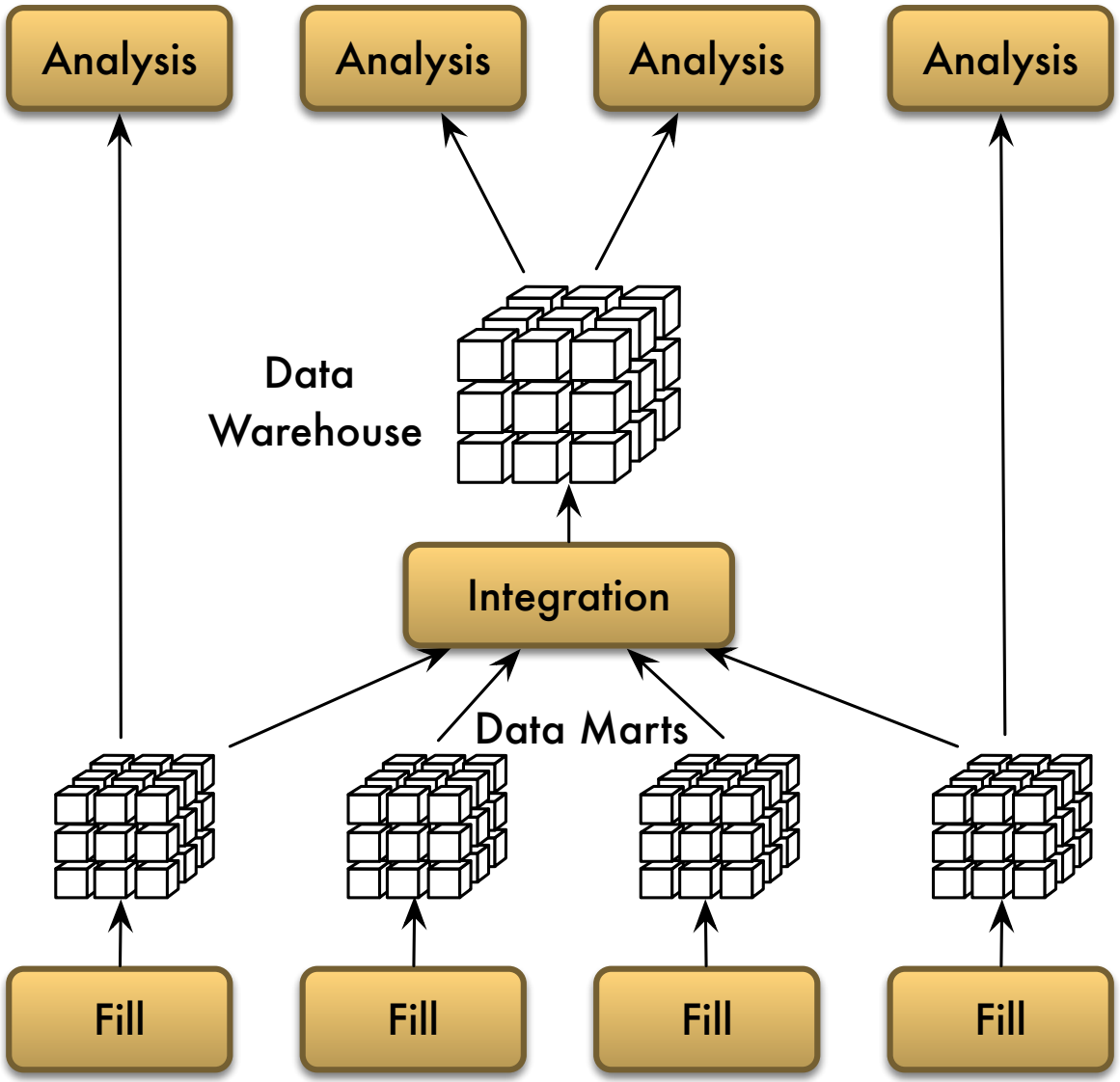
Dependent Data Marts: Extraction process

- Structural extracts
  - Limited to parts of the schema
  - Example: only certain metrics or dimensions
- Content-based extracts
  - Content-based restriction
  - Example: only certain branches or the last year's result
- Aggregated extracts
  - Reducing the granularity
  - Example: restriction on monthly results

Independent Data Marts

- Independently created "small" data warehouses (e.g., of individual organizations).
- Subsequent integration and transformation
- Problems:
  - Different analysis views (Data Mart, global Data Warehouse)
  - Consistency of the analysis due to additional transformation

Independent Data Marts



Analysis tools

- Business Intelligence Tools
- Task:
  - Presentation of the data collected
  - Interactive navigation
  - Analysis options
- Analysis:
  - Simple arithm. operations (e.g., aggregation) ... complex statistical analysis (e.g., data mining)
  - Preparation of the results for further processing or forwarding

Analysis tools: Representation I

- Tables
  - Pivot Tables: = crosstabs
    feature values in the row and column header
  - Analyzing by interchanging rows and columns
  - Change of table dimensions
  - Nesting of table dimensions

Revenue		Beer	Red wine	**Summe**
2009	Sachsen-Anhalt	45	32	77
	Thüringen	52	21	73
	Summe	97	53	150
2010	Sachsen-Anhalt	60	37	97
	Thüringen	58	20	78
	Summe	118	57	175

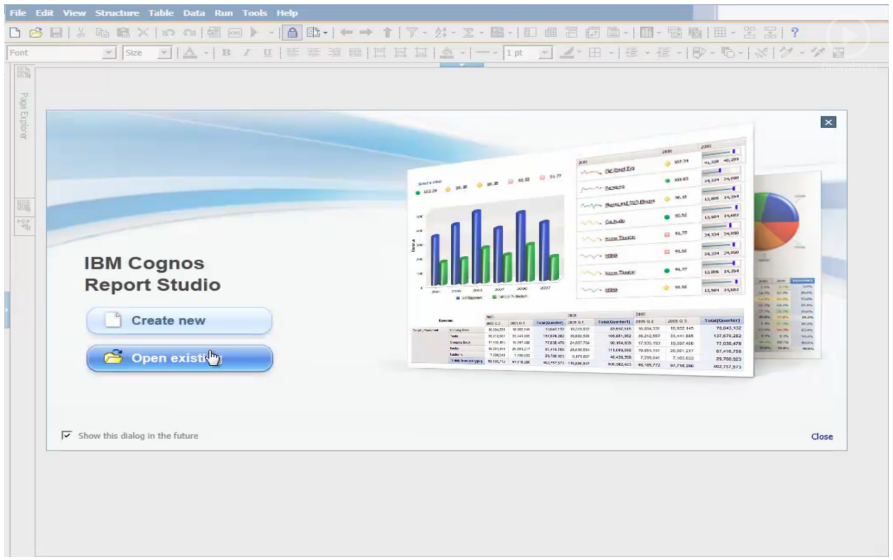
Analysis tools: Representation II

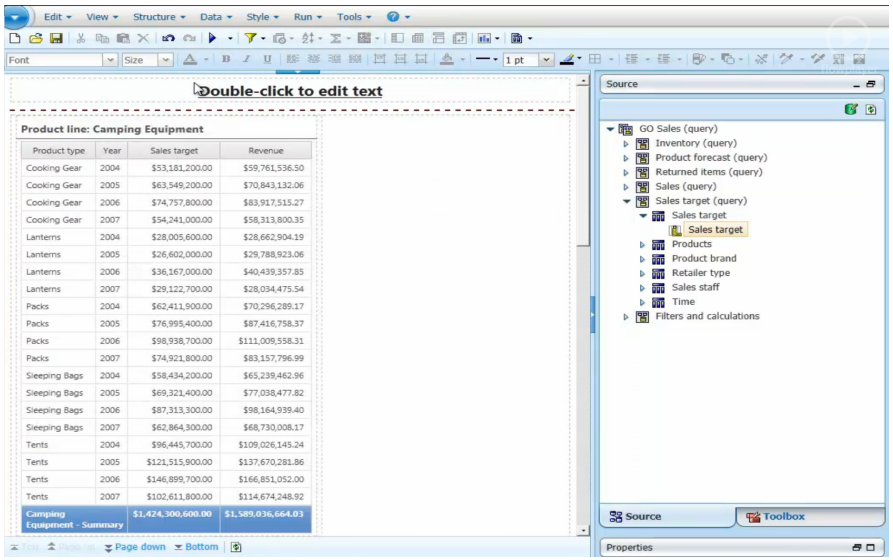
- Graphics
  - Visualization of large data sets
  - Net, dot, surface graphs
- Text and multimedia elements
  - Addition of audio or video data
  - Inclusion of document management systems

Analysis tools: Functionality

- Data Access
  - Reporting Tools
  - Reading of data, changing Presentation in reports
  - Presentation in reports
  - "Traffic lights": rule-based formatting
  - Base: SQL

Analysis tools: Example [Cognos, 2012]





Analysis tools: Functionality

- OLAP
  - Interactive data analysis, classification navigation
  - Reports with aggregated values (metrics / indicators)
  - Navigation operations:
    - ★ Drill Down,
    - ★ Roll Up,
    - ★ Drill Across,
    - ★ Dice und
    - ★ Slice
  - Aggregation and calculation functions (statistic, economic)
  - Validating hypotheses, plausibility check

Analysis tools: Example [Cognos, 2012]

IBM Cognos Viewer

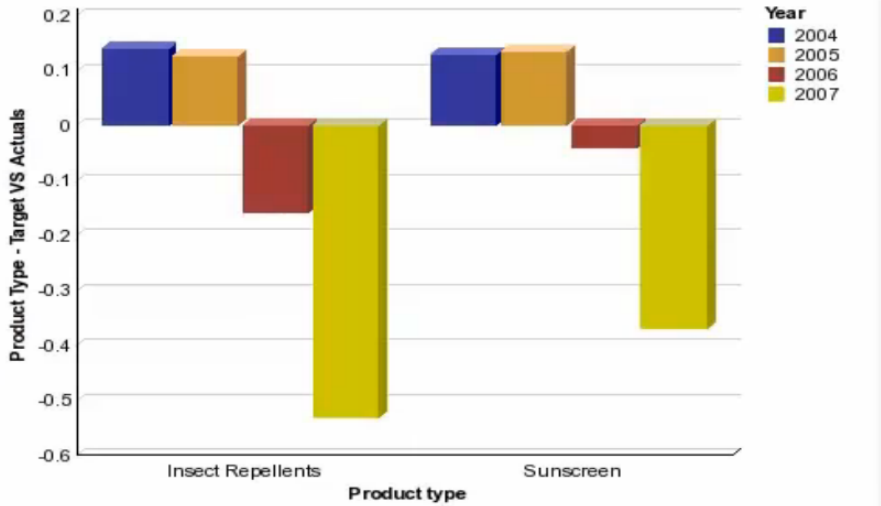
bob business | About

Revenue Performance Details

Product Line = Outdoor Protection ... Product Type = Insect Repellents, Sunscreen

Product line: Outdoor Protection

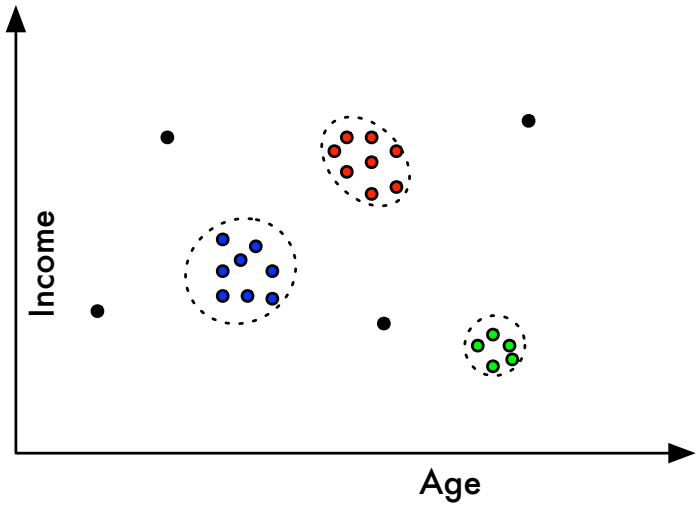
Product type	Year	Sales target	Revenue	Product Type - Target VS Actuals
Sunscreen	2004	$9,998,400.00	$11,298,443.87	13.00%
	2005	$9,295,600.00	$10,538,683.67	13.37%
	2006	$3,485,900.00	$3,342,648.85	-4.11%
	2007	$2,473,840.00	$1,561,978.22	-36.86%
Sunscreen - Summary		$25,253,740.00	$26,741,754.61	5.89%
Insect Repellents	2004	$15,750,000.00	$17,964,327.13	14.06%
	2005	$10,276,300.00	$11,579,433.65	12.68%
	2006	$6,193,800.00	$5,217,019.63	-15.77%
	2007	$4,397,000.00	$2,062,062.11	-53.10%
Insect Repellents - Summary		$36,617,100.00	$36,822,842.52	0.56%
Outdoor Protection - Summary		$61,870,840.00	$63,564,597.13	2.74%
Overall - Summary		$61,870,840.00	$63,564,597.13	2.74%

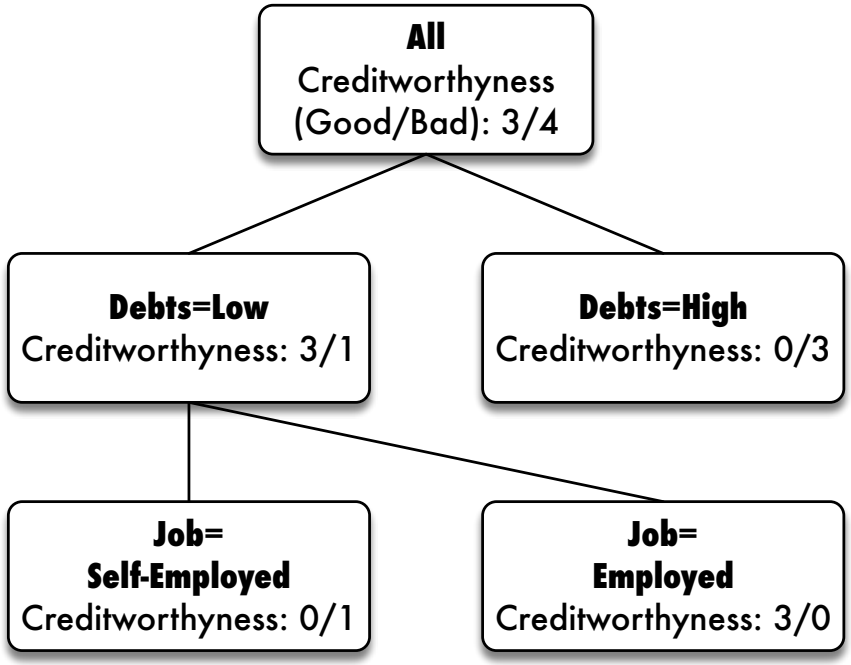


Analysis tools: Functionality

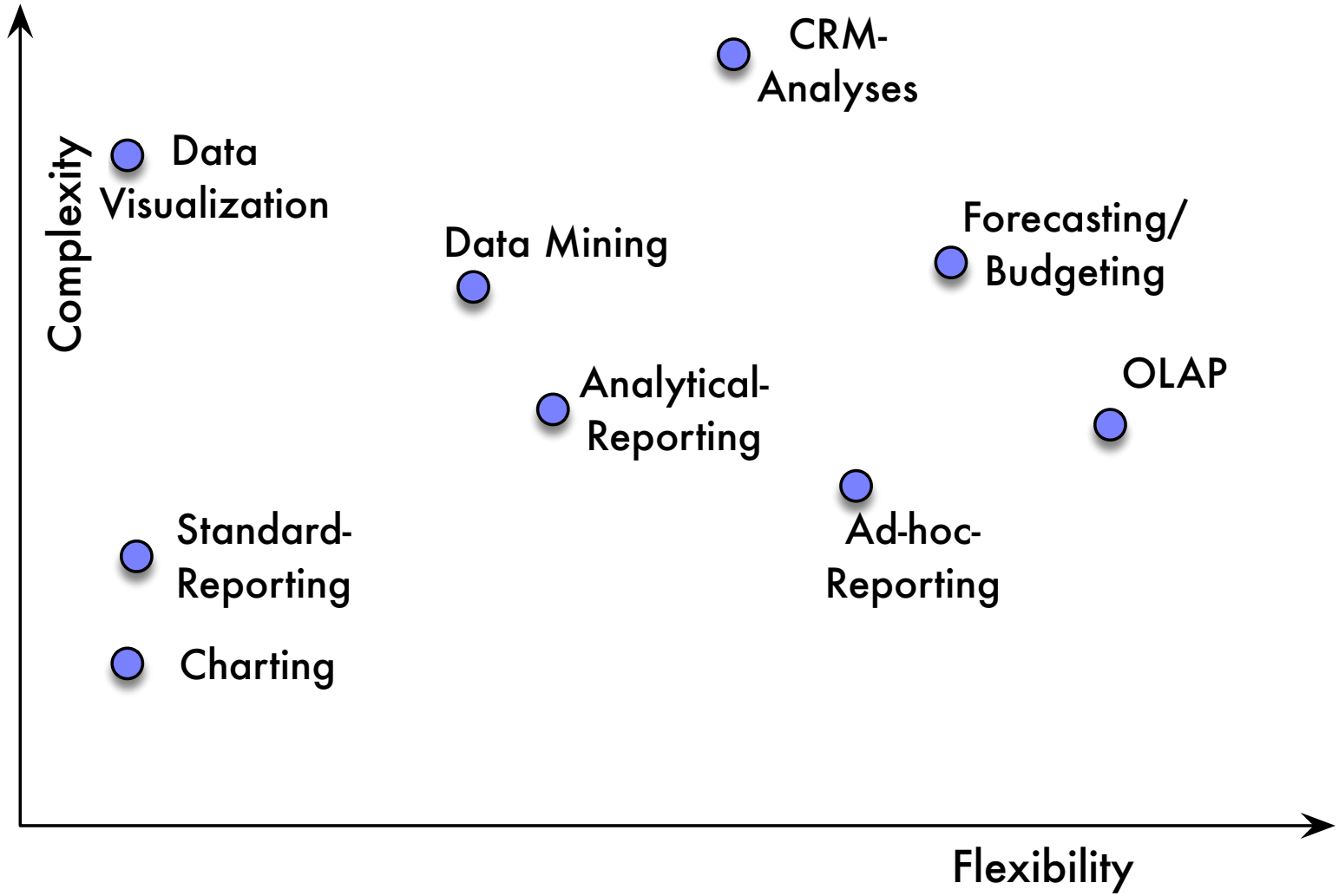
- Data Mining
  - Uncovering previously unknown relationships
    $\rightarrow$ Patterns, paths, rules
  - Methods (among others):
    - Classification: assignment of data to predefined classes
    - Association rules
    - Clustering: segmentation, i.e., grouping data regarding their characteristic values
    - Forecast

Data Mining: Examples





Types of analyses



Analysis tools: Implementation

- Standard Reporting:
  - Reporting tools of classical reporting
- Record books:
  - Graphical development environment for creating presentations of tables, graphs, etc.
- Ad-hoc Query & Reporting:
  - Tools for the creation and presentation of reports
  - Hide database connection and query languages

Analysis tools: Implementation

- Analysis Clients:
  - Tools for multidimensional analysis
  - Include navigation, manipulation (computing), advanced analysis and presentation functions
- Spreadsheet add-ins:
  - Extension of spreadsheets for data connection and navigation
- Development Environments:
  - Supporting the development of own analytic applications
  - Provision of operations on multidimensional data

Repository

- Task:
  - Storing the metadata of the DW system
- Metadata:
  - Information simplifying the construction, maintenance and administration of the DW system and enabling information retrieval
  - Examples:
    - Database schemas,
    - Access rights,
    - Process information (processing steps and parameters), etc.

Metadata Manager

- Tasks:
  - Control of the metadata management
  - Access, query, navigation
  - Version and configuration management
- Forms:
  - General use: extensible base schema
  - Tool-specific: fixed part of tools
- Frequently integration and exchange between decentralized metadata management systems necessary

Summary

- Reference architecture for Data Warehouse systems
- Process of the Data Warehousing
- Roles of components
- Data Marts as extracts of the DW
- Analysis tools: Classification and examples