

# Chapter IV: OLAP

## Knowledge Discovery in Databases

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## Chapter IV: Data warehousing and online analytical processing

### **Data warehouse: basic concepts.**

Data-warehouse modeling: data cube and OLAP.

Data-warehouse design and usage.

Data-warehouse Implementation.

Data generalization by attribute-oriented induction.

Summary.

## What is a data warehouse?

**Defined in many different ways, but not rigorously:**

A **decision-support** database that is **maintained separately** from the organization's operational database.

Supports information processing by providing a solid platform of **consolidated, historical data** for analysis.

**Famous:**

*A data warehouse is a **subject-oriented, integrated, time-variant, and nonvolatile** collection of data in support of management's decision-making process.*

– W. H. Inmon.

**Data warehousing:** The process of constructing and using data warehouses.

## Data warehouse – subject-oriented

**Organized around major subjects.**

Such as customer, product, sales.

**Focusing on the modeling and analysis of data for decision makers.**

Not on daily operations or transaction processing.

**Provide a simple and concise view around particular subject issues.**

By excluding data that are not useful in the decision-support process.

## Data warehouse – integrated

**Constructed by integrating multiple heterogeneous data sources.**

Relational databases, flat files, online transaction records, ...

**Data-cleaning and data-integration techniques are applied.**

Ensure consistency in naming conventions, encoding structures, attribute measures, etc.  
among different data sources.

E.g., hotel price: currency, tax, breakfast covered, etc.

When data is moved to the warehouse, it is converted.

ETL – Extraction, Transformation, Loading, see below.

## Data warehouse – time variant

The **time horizon** for a data warehouse is **significantly longer** than that of operational systems.

Operational database: current-value data.

Data warehouse: provide information from a historical perspective, e.g. past 5 – 10 years.

**Every key structure in the data warehouse contains an element of time, explicitly or implicitly.**

The key of operational data may or may not contain a "time element."

## Data warehouse – nonvolatile

### A **physically separate** store of data.

Transformed from the operational environment.

By **copying**.

### No operational update of data:

Hence, does not require transaction processing,  
i.e. no logging, recovery, concurrency control, etc.

Requires only three operations:

- Initial loading of data.

- Refresh (update, often periodically, e.g. over night).

- Access of data.

## OLTP vs. OLAP

	OLTP	OLAP
<b>users</b>	clerk, IT professional	knowledge worker
<b>function</b>	day-to-day operations	decision support
<b>DB design</b>	application-oriented	decision support
<b>data</b>	current, up-to-date; detailed, flat relational; isolated	historical; summarized, multidimensional, integrated, consolidated
<b>usage</b>	repetitive	ad-hoc
<b>access</b>	read/write; index/hash on primary key	lots of scans
<b>unit of work</b>	short, simple transaction	complex query
<b>#-records accessed</b>	10	$10^6$
<b>#-users</b>	1000	100
<b>DB size</b>	100 MB to GB	100 GB to TB
<b>quantification</b>	transaction throughput	query throughput, response



## Why a separate data warehouse?

### High performance for both systems:

**DBMS:** tuned for OLTP; Access methods, indexing concurrency control, recovery.

**Warehouse:** tuned for OLAP; Complex OLAP queries, multidimensional view, consolidation.

### Different functions and different data:

Missing data:

Decision support (DS) requires **historical data**  
which operational DBs do not typically maintain.

Data consolidation:

DS requires **consolidation** (aggregation, summarization)  
of data from heterogeneous sources.

Data quality:

Different sources typically use inconsistent data representations,  
codes and formats which have to be reconciled.

**Note: There are more and more systems which perform OLAP analysis directly on relational databases.**

## Class characterization: an initial relation (I)

Name	Gender	Major	Birth place	Birth date	Residence	Phone number	GPA
Jim	M	CS	Vancouver, BC, Canada	08-21-76	3511 Main St., Richmond	687-4598	3.67
Scott Lachance	M	CS	Montreal, Que, Canada	28-07-75	345 1st Ave., Richmond	253-9106	3.70
Laura Lee	F	Physics	Seattle, WA, USA	25-08-70	125 Austin Ave., Burnaby	420-5232	3.83
Removed	Retained	Sci, Eng, Bus	Country	Age range	City	Removed	Excl, Vg,...

## Class characterization: prime generalized relation (II)

Gender	Major	Birth region	Age range	Residence	GPA	Count
M	Science	Canada	20-35	Richmond	Very good	16
F	Science	Foreign	25-30	Burnaby	Excellent	22
...	...	...	...	...	...	...

## Class characterization: an example (III)

Cross-table of birth region and gender:

	Canada	Foreign	Total
M	16	14	30
F	10	22	32
Total	26	36	62

## Basic principles of attribute-oriented induction

### Data focusing:

Task-relevant data, including dimensions  
The result is the **initial relation**.

### Attribute removal:

Remove attribute A, if there is a large set of distinct values for A,  
but (1) there is no generalization operator on A,  
or (2) A's higher-level concepts are expressed in terms of other attributes.

### Attribute generalization:

If there is a large set of distinct values for A,  
and there exists a **set of generalization operators** on A,  
then select an operator and generalize A.

### Attribute-threshold control:

Typical 2-8, specified/default.

### Generalized-relation-threshold control:

Control the final relation/rule size.

## Attribute-oriented induction: basic algorithm

### InitialRel:

Query processing of task-relevant data, deriving the initial relation.

### PreGen:

Based on the analysis of the number of distinct values in each attribute, determine generalization plan for each attribute: removal? Or how high to generalize?

### PrimeGen:

Based on the PreGen plan, perform generalization to the right level to derive a "prime generalized relation", accumulating the counts.

### Presentation:

User interaction:

1. Adjust levels by drilling.
2. Pivoting.
3. Mapping into rules, cross tabs, visualization presentations.

## Presentation of generalized results

### Generalized relation:

Relations where some or all attributes are generalized, with counts or other aggregation values accumulated.

### Cross tabulation:

Mapping results into cross-tabulation form (similar to contingency tables).

Visualization techniques: pie charts, bar charts, curves, cubes, and other visual forms.

### Quantitative characteristic rules:

Mapping generalized result into characteristic rules with quantitative information associated with it, e.g.

$$\text{grad}(x) \wedge \text{male}(x) \implies \text{birth\_region}(x) \quad (1)$$

$$= \text{"Canada"}[t : 53\%] \vee \text{birth\_region}(x) \quad (2)$$

$$= \text{"foreign"}[t : 47\%]. \quad (3)$$

## Mining-class comparisons

**Comparison: Comparing two or more classes.**

**Method:**

Partition the set of relevant data into the **target class** and the **contrasting class(es)**.

Generalize both classes to the same high-level concepts (i.e. AOI).

Including aggregation.

Compare tuples with the same high-level concepts.

Present for each tuple its description and two measures.

Support – distribution within single class (counts, percentage).

Comparison – distribution between classes.

Highlight the tuples with strong discriminant features.

**Relevance Analysis:**

Find attributes (features) which best distinguish different classes.



## Concept description vs. cube-based OLAP

### Similarity:

- Data generalization.

- Presentation of data summarization at multiple levels of abstraction.

- Interactive drilling, pivoting, slicing and dicing.

### Differences:

- OLAP has systematic preprocessing, query independent, and can drill down to rather low level.

- AOI has automated desired-level allocation and may perform dimension-relevance analysis/ranking when there are many relevant dimensions.

- AOI works on data which are not in relational forms.

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## Summary

### **Data warehousing: multi-dimensional model of data.**

A data cube consists of dimensions and measures.

Star schema, snowflake schema, fact constellations.

OLAP operations: drilling, rolling, slicing, dicing and pivoting.

### **Data-warehouse architecture, design, and usage.**

Multi-tiered architecture.

Business-analysis design framework.

Information processing, analytical processing, data mining, OLAM (Online Analytical Mining).

### **Implementation: efficient computation of data cubes.**

Partial vs. full vs. no materialization.

Indexing OLAP data: Bitmap index and join index.

OLAP query processing.

OLAP servers: ROLAP, MOLAP, HOLAP.

### **Data generalization: attribute-oriented induction.**

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Thank you for your attention.  
**Any questions about the fourth chapter?**

Ask them now, or again, drop me a line:  
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