CS 412 Intro. to Data Mining

Chapter 4. Data Warehousing and On-line Analytical Processing

Jiawei Han, Computer Science, Univ. Illinois at Urbana-Champaign, 2017

Chapter 4: Data Warehousing and On-line Analytical Processing

- Data Warehouse: Basic Concepts
- Data Warehouse Modeling: Data Cube and OLAP
- Data Warehouse Design and Usage
- Data Warehouse Implementation
- Summary

What is a Data Warehouse?

- Defined in many different ways, but not rigorously

  ใช้สนับสนุนการตัดสินใจ

  - A decision support database that is maintained separately from the organization's operational database
  - Support information processing by providing a solid platform of consolidated, historical data for analysis

ต้องมีคำถาม/เป้าหมาย/ทำเพื่ออะไร การรวมจากหลายแหล่ง Data ที่ดึงมาอยู่ในช่วงเวลาไหน, เก็บตอนไหน

- "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 ที่ได้มาไม่เคลื่อนที่แล้ว

- 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, on-line transaction records
- Data cleaning and data integration techniques are applied.
  - Ensure consistency in naming conventions, encoding structures, attribute measures, etc. among different data sources
    - Ex. Hotel price: differences on currency, tax, breakfast covered, and parking
  - When data is moved to the warehouse, it is converted

Data Warehouse—Time Variant

- The time horizon for the data warehouse is significantly longer than that of operational systems
  - Operational database: current value data
  - Data warehouse data: 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
  - But the key of operational data may or may not contain “time element”

Data Warehouse—Nonvolatile

- Independence
  - A physically separate store of data transformed from the operational environment
- Static: Operational update of data does not occur in the data warehouse environment
  - Does not require transaction processing, recovery, and concurrency control mechanisms
  - Requires only two operations in data accessing:
    - *initial loading of data* and *access of data*

OLTP vs. OLAP

- OLTP: Online transactional processing
  - DBMS operations
  - Query and transactional processing
- OLAP: Online analytical processing
  - Data warehouse operations
  - Drilling, slicing, dicing, etc.

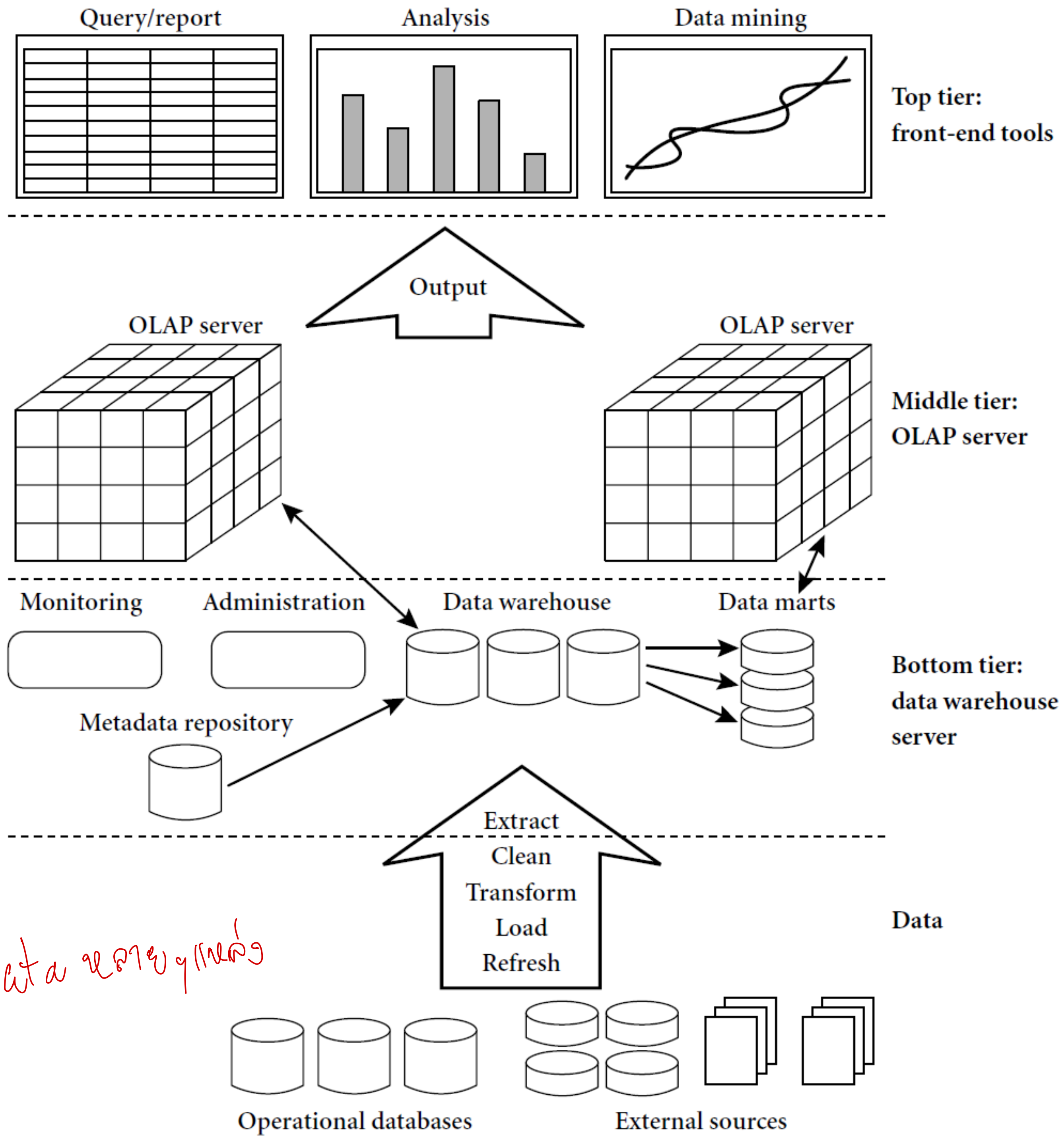
	OLTP	**OLAP**
users	clerk, IT professional	knowledge worker
function	day to day operations	decision support
DB design	application-oriented	subject-oriented
data	current, up-to-date detailed, flat relational isolated	historical, summarized, multidimensional integrated, consolidated
usage	repetitive	ad-hoc
access	read/write index/hash on prim. key	lots of scans
unit of work	short, simple transaction	complex query
# records accessed	tens	millions
#users	thousands	hundreds
DB size	100MB-GB	100GB-TB
metric	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 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

Data Warehouse: A Multi-Tiered Architecture

- Top Tier: Front-End Tools
- Middle Tier: OLAP Server
- Bottom Tier: Data Warehouse Server
- Data



Data หลายๆแหล่ง

Three Data Warehouse Models

- **Enterprise warehouse**
  - Collects all of the information about subjects spanning the entire organization
- **Data Mart**
  - A subset of corporate-wide data that is of value to a specific groups of users
  - Its scope is confined to specific, selected groups, such as marketing data mart
    - Independent vs. dependent (directly from warehouse) data mart
- **Virtual warehouse**
  - A set of views over operational databases
  - Only some of the possible summary views may be materialized

Extraction, Transformation, and Loading (ETL)

- **Data extraction**
  - get data from multiple, heterogeneous, and external sources
- **Data cleaning**
  - detect errors in the data and rectify them when possible
- **Data transformation**
  - convert data from legacy or host format to warehouse format
- **Load**
  - sort, summarize, consolidate, compute views, check integrity, and build indicies and partitions
- **Refresh**
  - propagate the updates from the data sources to the warehouse

Metadata Repository

- **Meta data** is the data defining warehouse objects. It stores:
  - Description of the structure of the data warehouse
    - schema, view, dimensions, hierarchies, derived data defn, data mart locations and contents
  - Operational meta-data
    - data lineage (history of migrated data and transformation path), currency of data (active, archived, or purged), monitoring information (warehouse usage statistics, error reports, audit trails)
  - The algorithms used for summarization
  - The mapping from operational environment to the data warehouse
  - Data related to system performance
    - warehouse schema, view and derived data definitions
  - Business data
    - business terms and definitions, ownership of data, charging policies

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From Tables and Spreadsheets to Data Cubes

- A **data warehouse** is based on a multidimensional data model which views data in the form of a data cube
- A data cube, such as sales, allows data to be modeled and viewed in multiple dimensions เก็บใน data warehouse ไว้สองอัน
  - **Dimension tables**, such as item (item_name, brand, type), or time(day, week, month, quarter, year) ไว้อธิบายว่า สามารถจำแนกเป็นอย่างไร
  - **Fact table** contains **measures** (such as dollars_sold) and keys to each of the related dimension tables เก็บตัวเลข
- **Data cube**: A lattice of cuboids
  - In data warehousing literature, an n-D base cube is called a **base cuboid**
  - The top most 0-D cuboid, which holds the highest-level of summarization, is called the **apex cuboid**
  - The lattice of cuboids forms a **data cube**.

2 มุมมอง

2D

ร้านนี้ขายของได้เท่าไหร่?

Table 4.2: A 2-D view of sales data for *AllElectronics* according to the dimensions *time* and *item*, where the sales are from branches located in the city of Vancouver. The measure displayed is *dollars_sold* (in thousands).

***location* = "Vancouver"**

item (type) ชนิดของสินค้า

เวลา *time* (quarter)	*home entertainment*	*computer*	*phone*	*security*
Q1	605	825	14	400
Q2	680	952	31	512
Q3	812	1023	30	501
Q4	927	1038	38	580

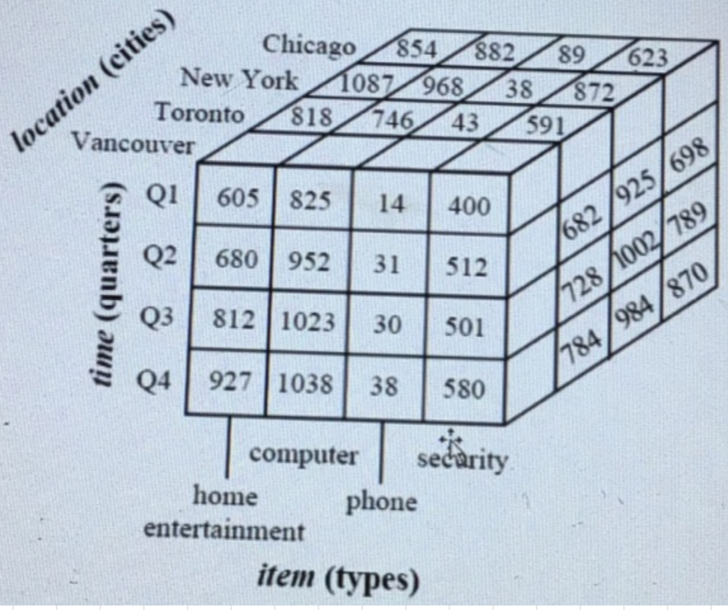
3D

3 มุมมอง

Table 4.3: A 3-D view of sales data for *AllElectronics*, according to the dimensions *time*, *item*, and *location*. The measure displayed is *dollars_sold* (in thousands).

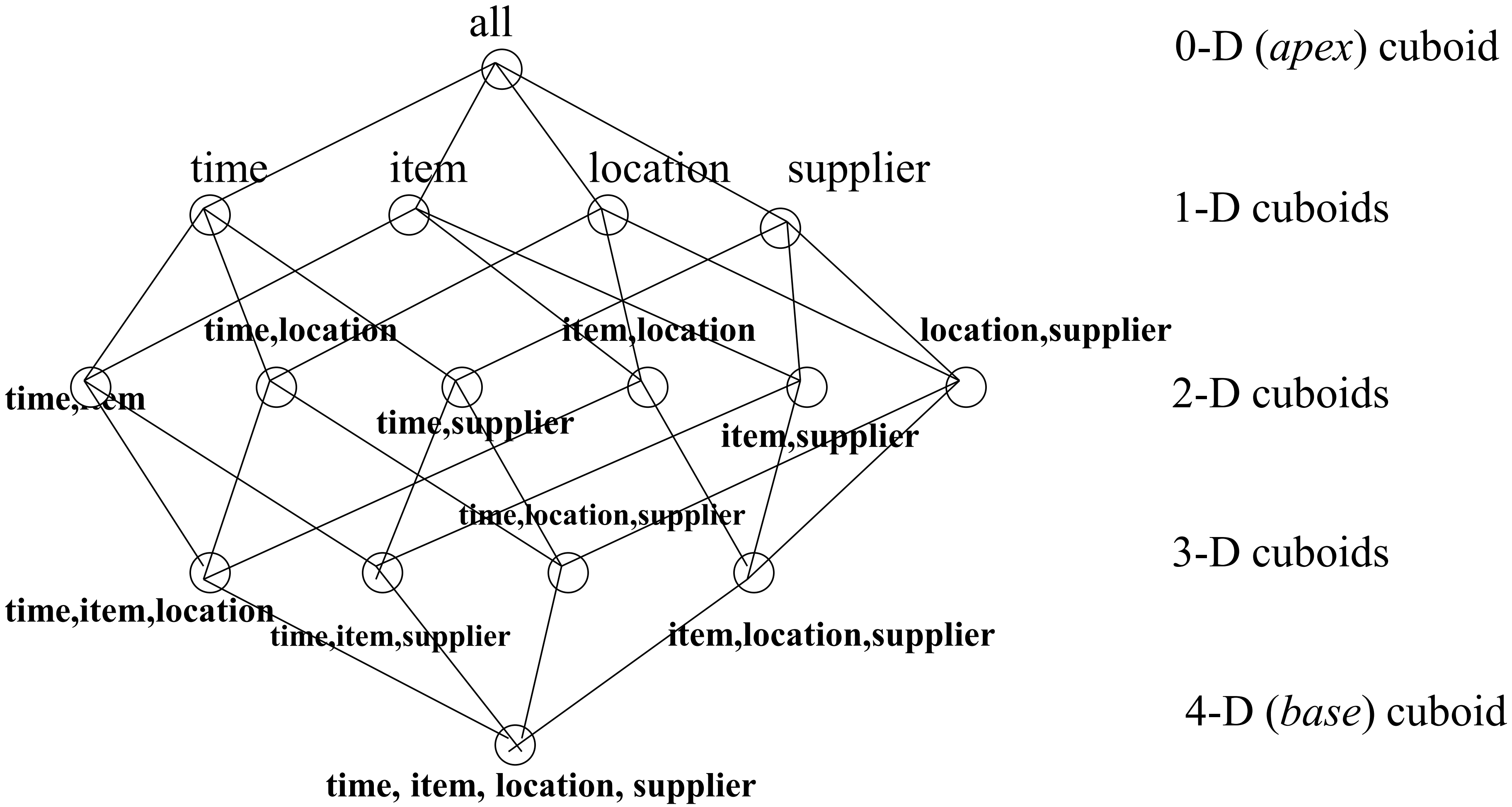
	location = "Chicago"				*location* = "New York"				*location* = "Toronto"				*location* = "Vancouver"			
	item				*item*				*item*				*item*			
time	*home ent.*	*comp.*	*phone*	*sec.*	*home ent.*	*comp.*	*phone*	*sec.*	*home ent.*	*comp.*	*phone*	*sec.*	*home ent.*	*comp.*	*phone*	*sec.*
Q1	854	882	89	623	1087	968	38	872	818	746	43	591	605	825	14	400
Q2	943	890	64	698	1130	1024	41	925	894	769	52	682	680	952	31	512
Q3	1032	924	59	789	1034	1048	45	1002	940	795	58	728	812	1023	30	501
Q4	1129	992	63	870	1142	1091	54	984	978	864	59	784	927	1038	38	580

3D



location (cities)
Chicago
New York
Toronto
Vancouver
854
882
89
623
1087
968
38
872
818
746
43
591
698
925
682
789
1002
728
870
984
784
time (quarters)
Q1
Q2
Q3
Q4
605
825
14
400
680
952
31
512
812
1023
30
501
927
1038
38
580
computer
security
home entertainment
phone
item (types)

Data Cube: A Lattice of Cuboids



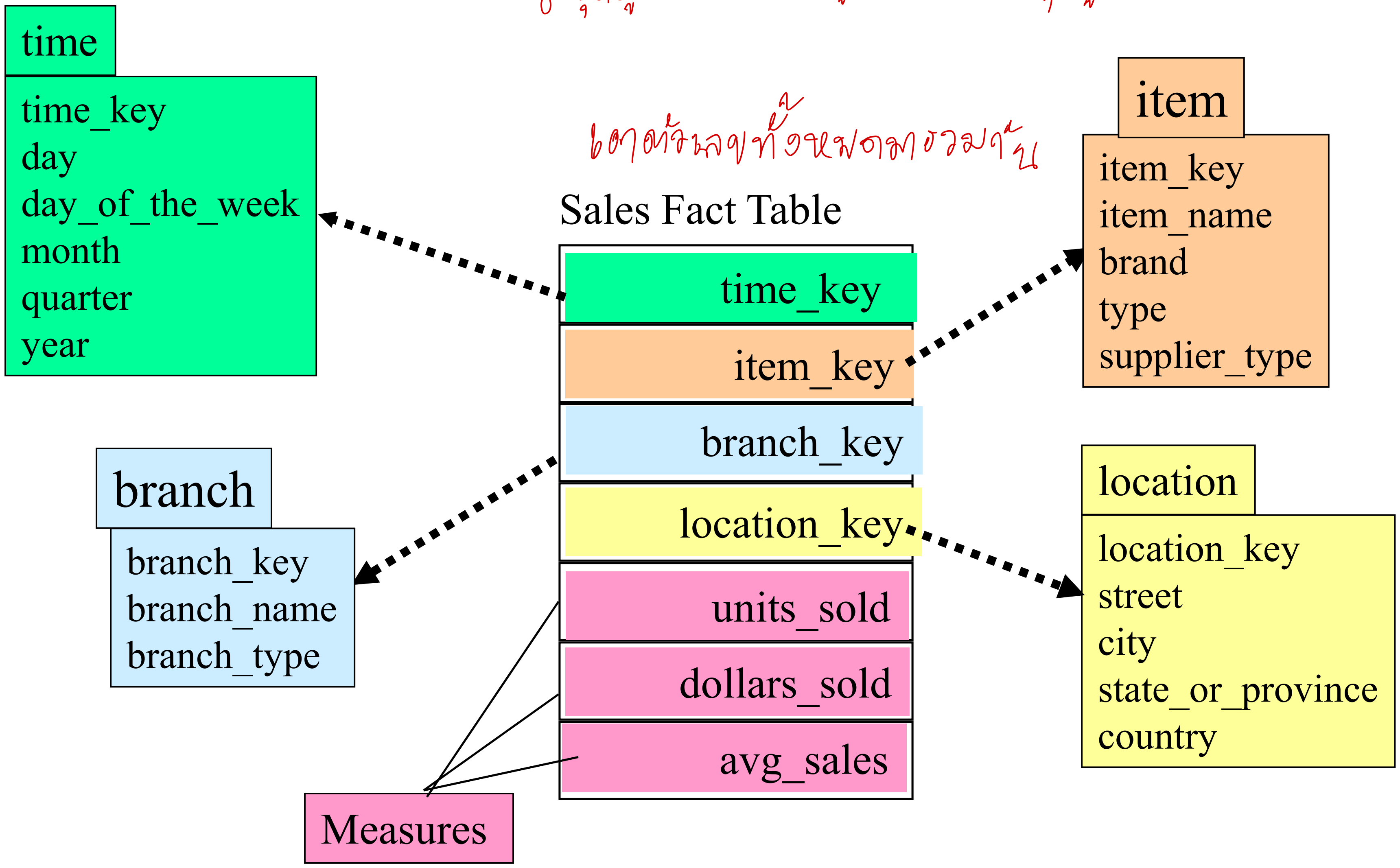
Conceptual Modeling of Data Warehouses

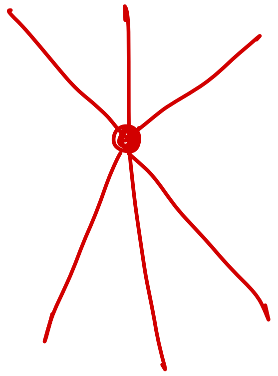
- Modeling data warehouses: dimensions & measures
  - Star schema: A fact table in the middle connected to a set of dimension tables
  - Snowflake schema: A refinement of star schema where some dimensional hierarchy is normalized into a set of smaller dimension tables, forming a shape similar to snowflake
  - Fact constellations: Multiple fact tables share dimension tables, viewed as a collection of stars, therefore called galaxy schema or fact constellation

Star Schema: An Example

มีจุดศูนย์ 1 อัน แล้วถูกแตกออกไปจากจุดศูนย์กลาง

เอาตัวเลขทั้งหมดมารวมกัน





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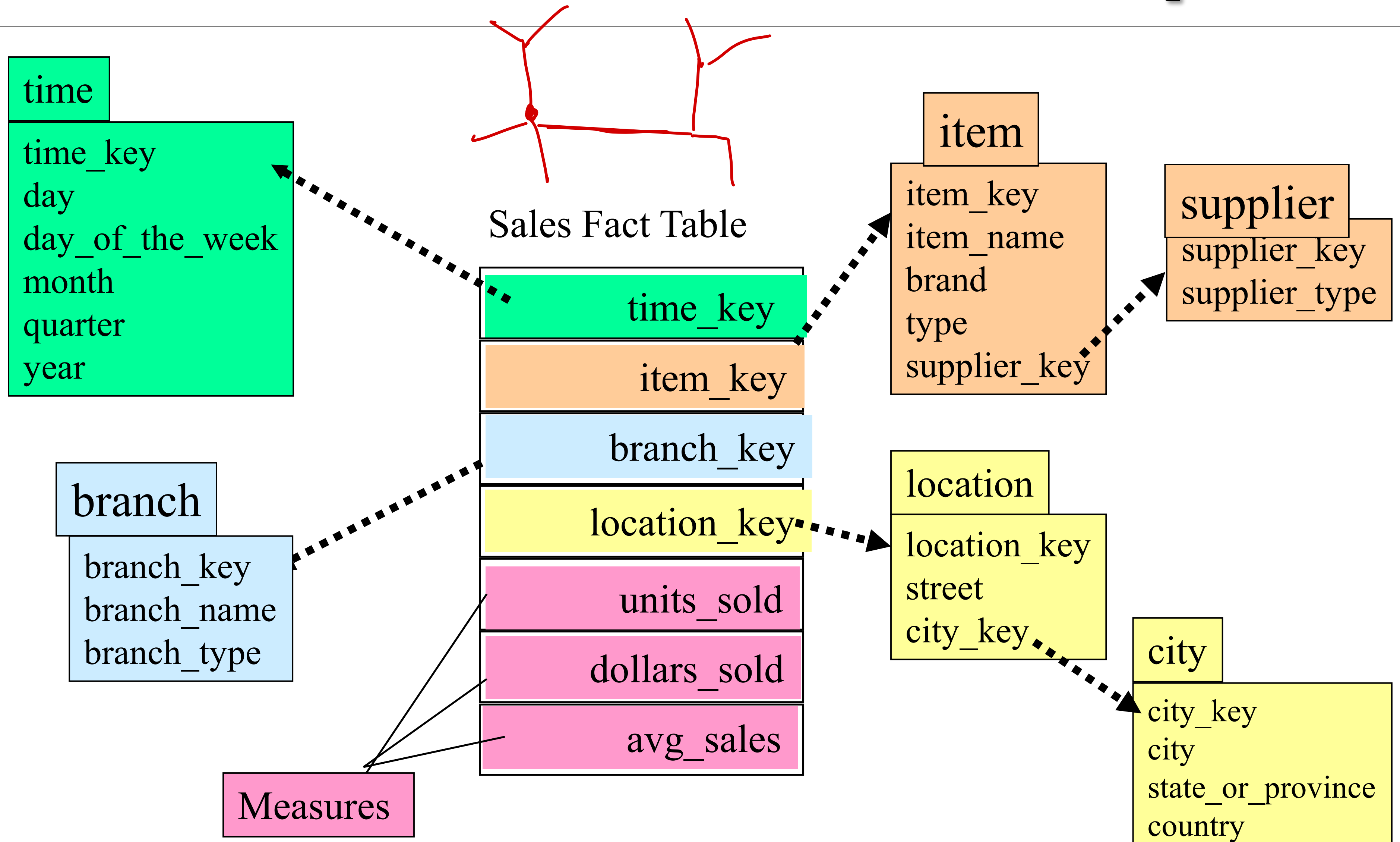
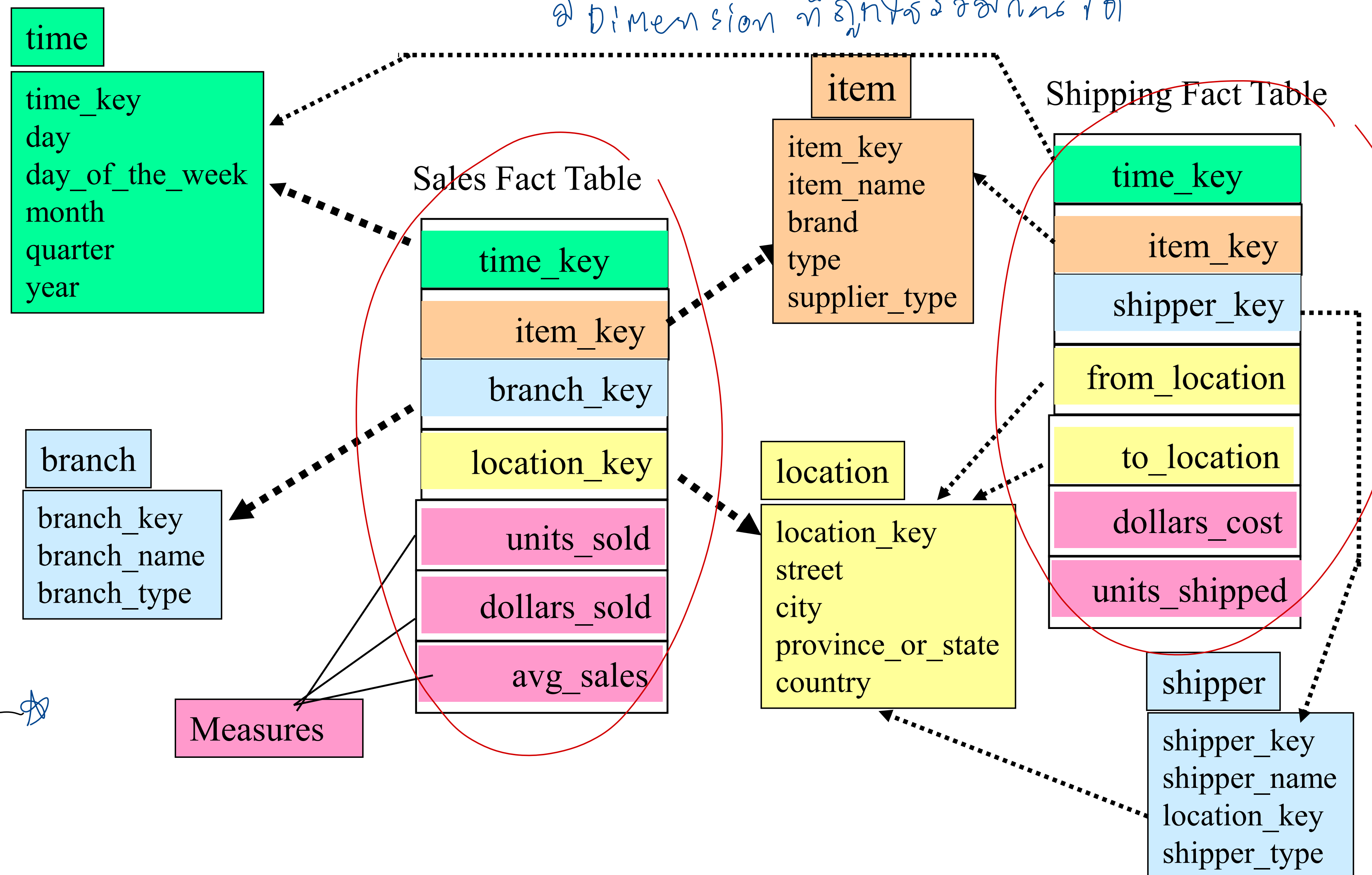
Snowflake Schema: An Example

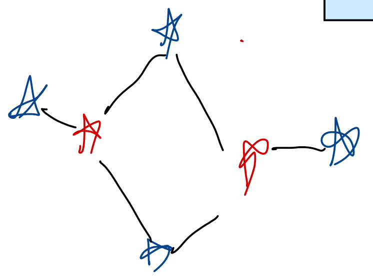


กลุ่มดาว ที่รวมกัน

Fact Constellation: An Example

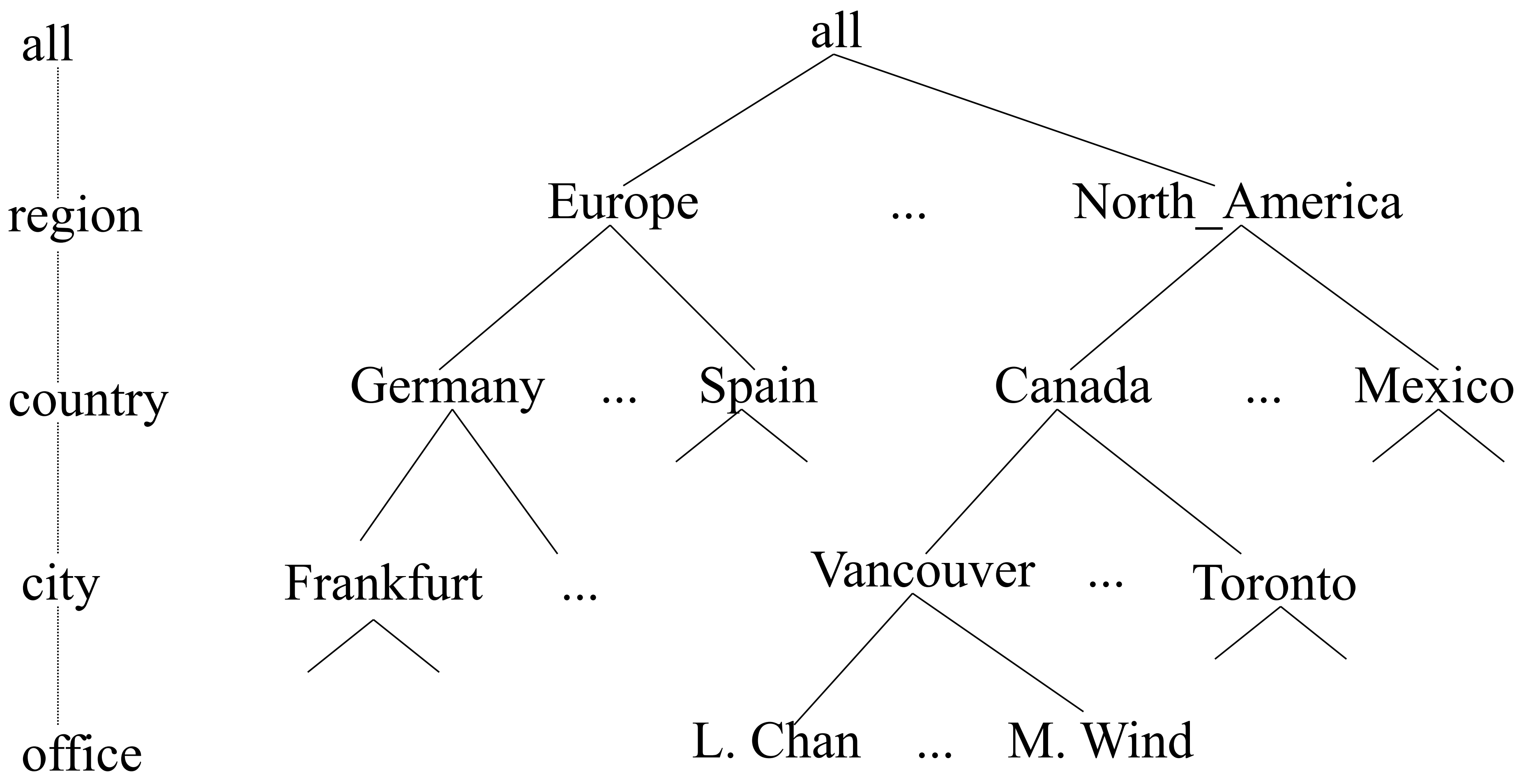
มี Dimension ที่ถูกใช้ร่วมกันได้





สามารถแบ่งแยกย่อยได้อีก

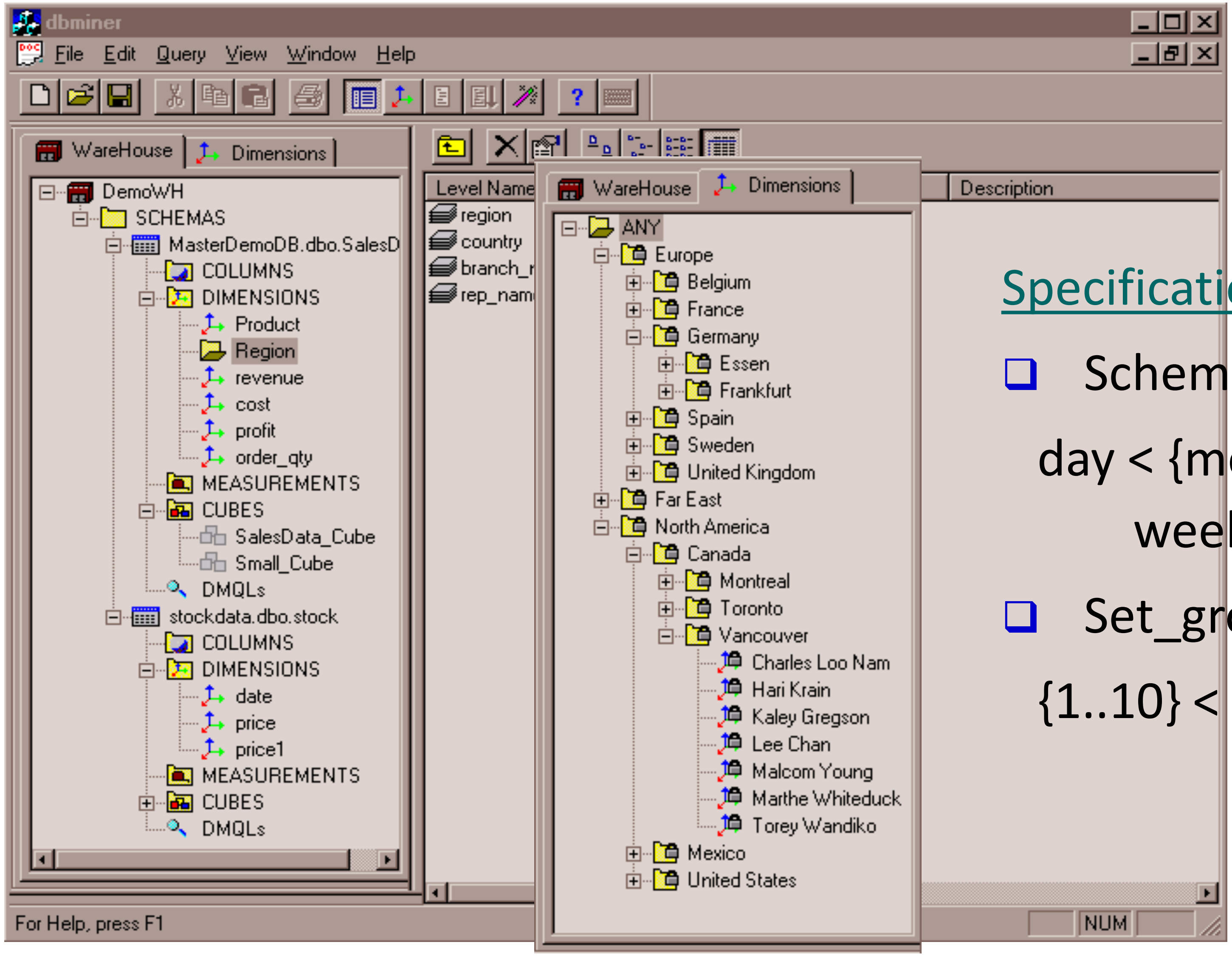
A Concept Hierarchy for a Dimension (location)



Data Cube Measures: Three Categories

- Distributive: if the result derived by applying the function to *n* aggregate values is the same as that derived by applying the function on all the data without partitioning
  - E.g., count(), sum(), min(), max()
- Algebraic: if it can be computed by an algebraic function with *M* arguments (where *M* is a bounded integer), each of which is obtained by applying a distributive aggregate function
  - avg(x) = sum(x) / count(x)
  - Is min_N() an algebraic measure?   How about standard_deviation()?
- Holistic: if there is no constant bound on the storage size needed to describe a subaggregate.
  - E.g., median(), mode(), rank()

View of Warehouses and Hierarchies



Specification of hierarchies

- Schema hierarchy

  day < {month < quarter; week} < year

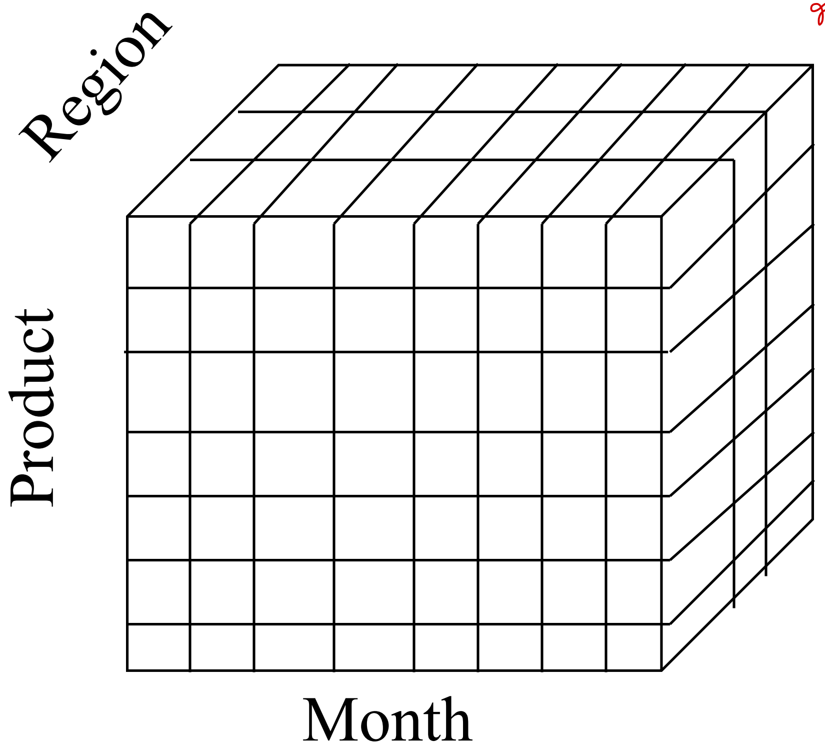
- Set_grouping hierarchy

  {1..10} < inexpensive

Multidimensional Data

แบ่งเป็นฟังก์ชันของ สินค้า เดือน ชาติ

- Sales volume as a function of product, month, and region

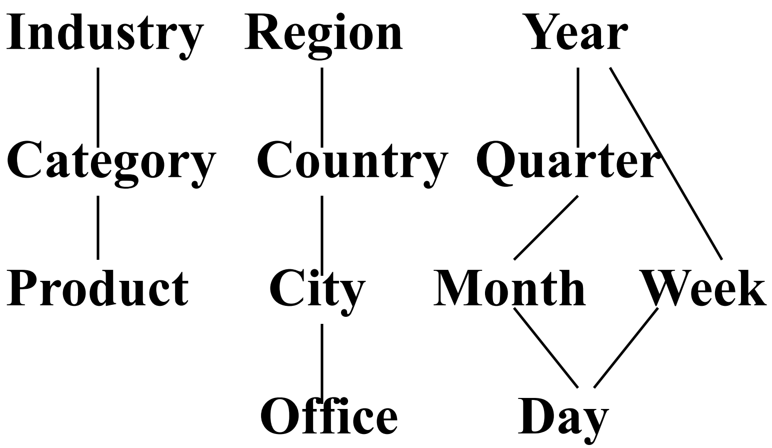


มองละเอียดมากขึ้น

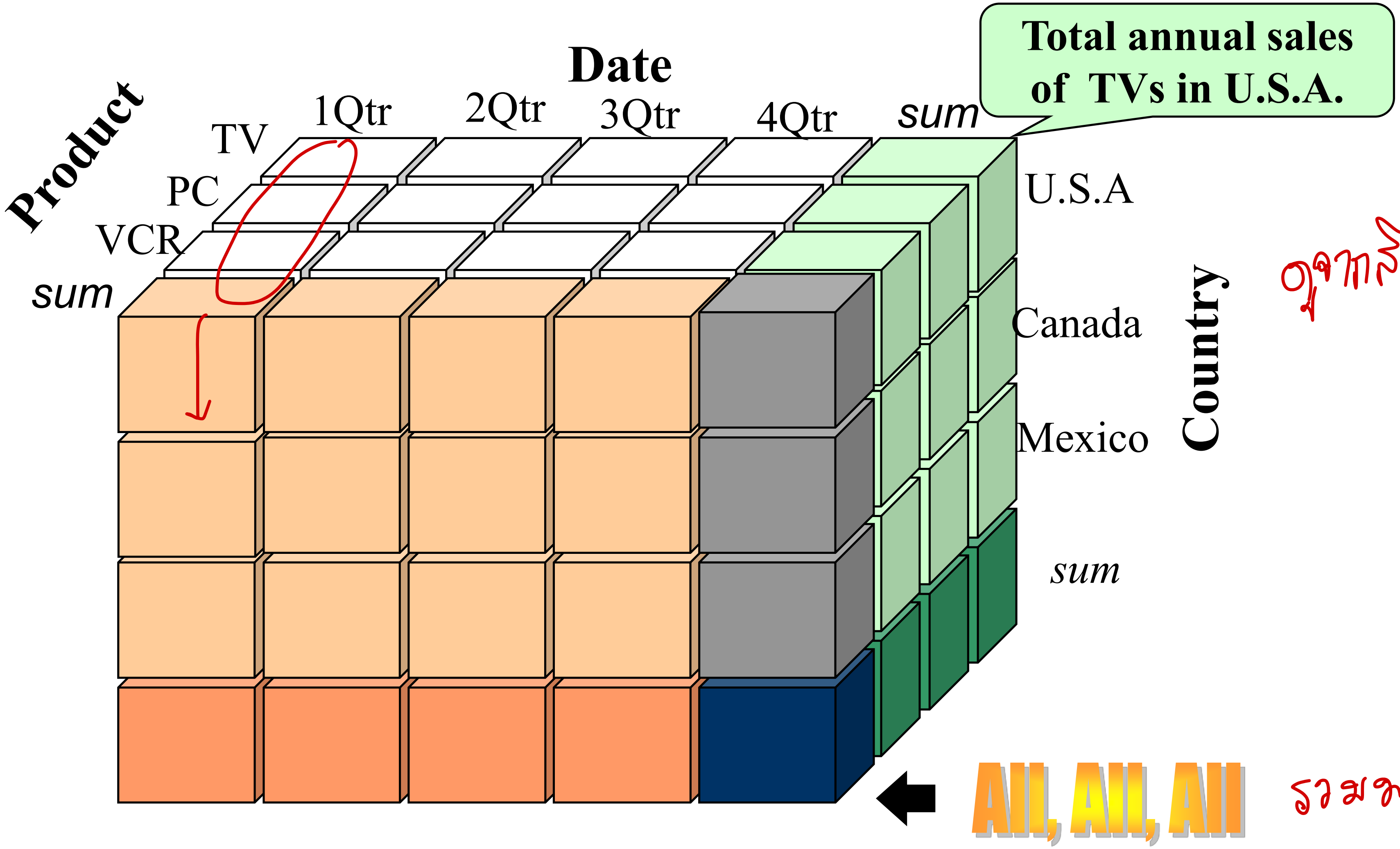
Dimensions: *Product, Location, Time*

Hierarchical summarization paths

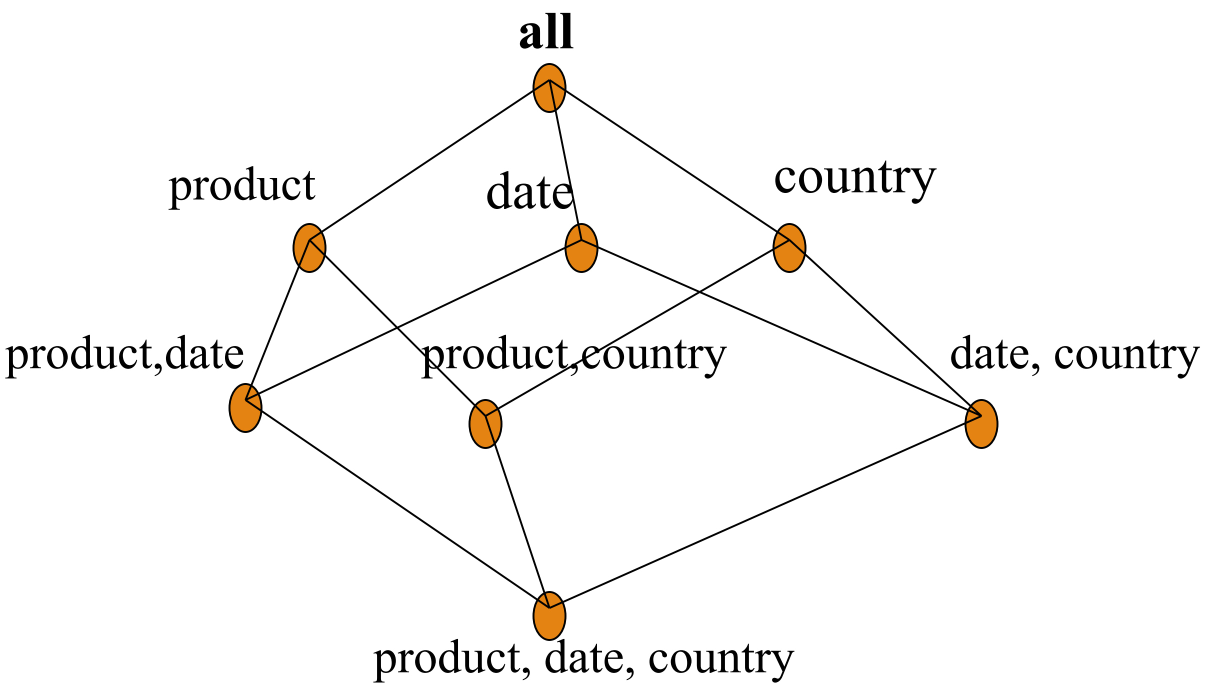
แบ่งแยกย่อยลงไป



A Sample Data Cube



Cuboids Corresponding to the Cube



0-D (*apex*) cuboid

1-D cuboids

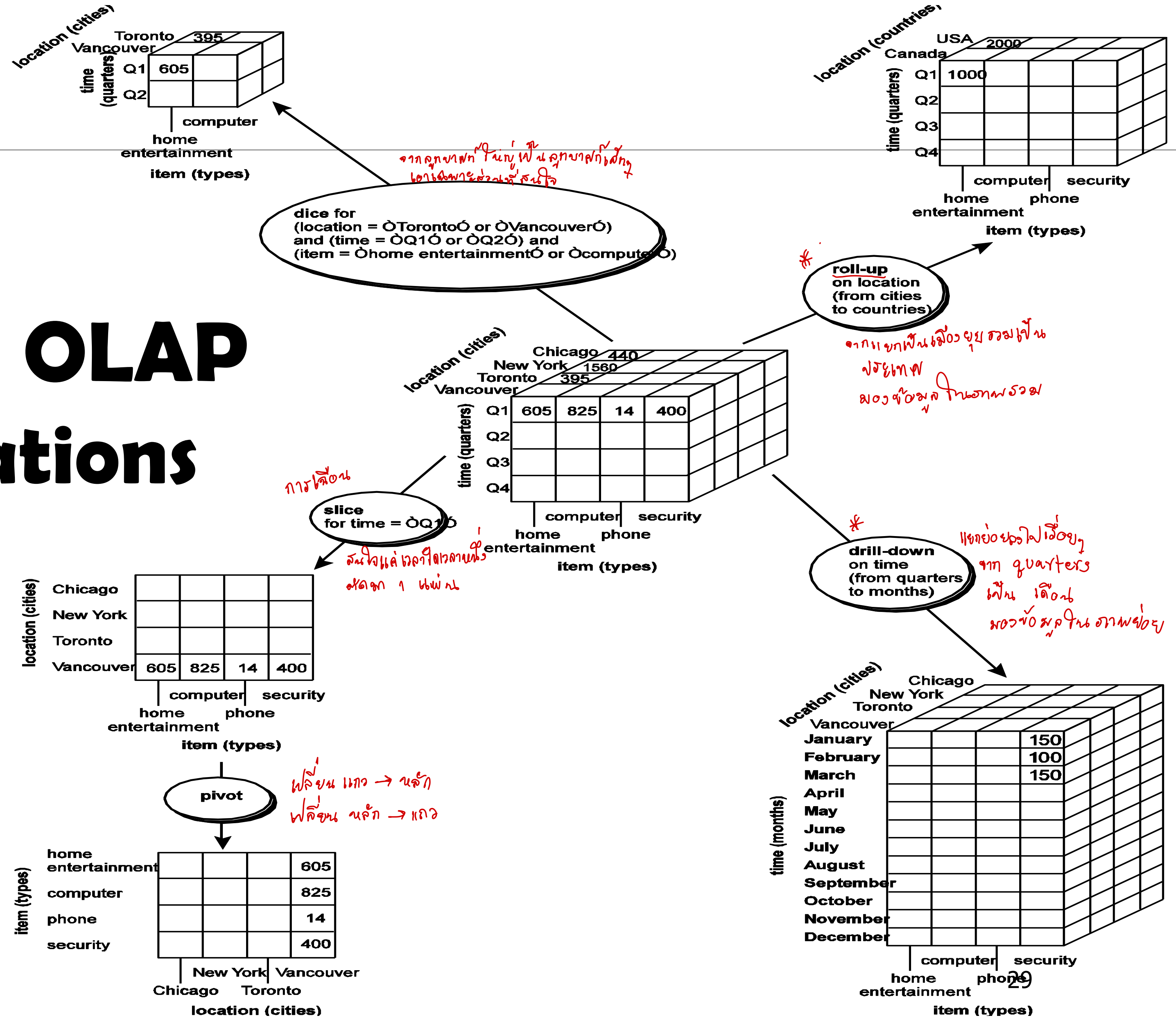
2-D cuboids

3-D (*base*) cuboid

Typical OLAP Operations

- Roll up (drill-up): summarize data
  - *by climbing up hierarchy or by dimension reduction*
- Drill down (roll down): reverse of roll-up
  - *from higher level summary to lower level summary or detailed data, or introducing new dimensions*
- Slice and dice: *project and select*
- Pivot (rotate):
  - *reorient the cube, visualization, 3D to series of 2D planes*
- Other operations
  - *Drill across: involving (across) more than one fact table*
  - *Drill through: through the bottom level of the cube to its back-end relational tables (using SQL)*

Typical OLAP Operations

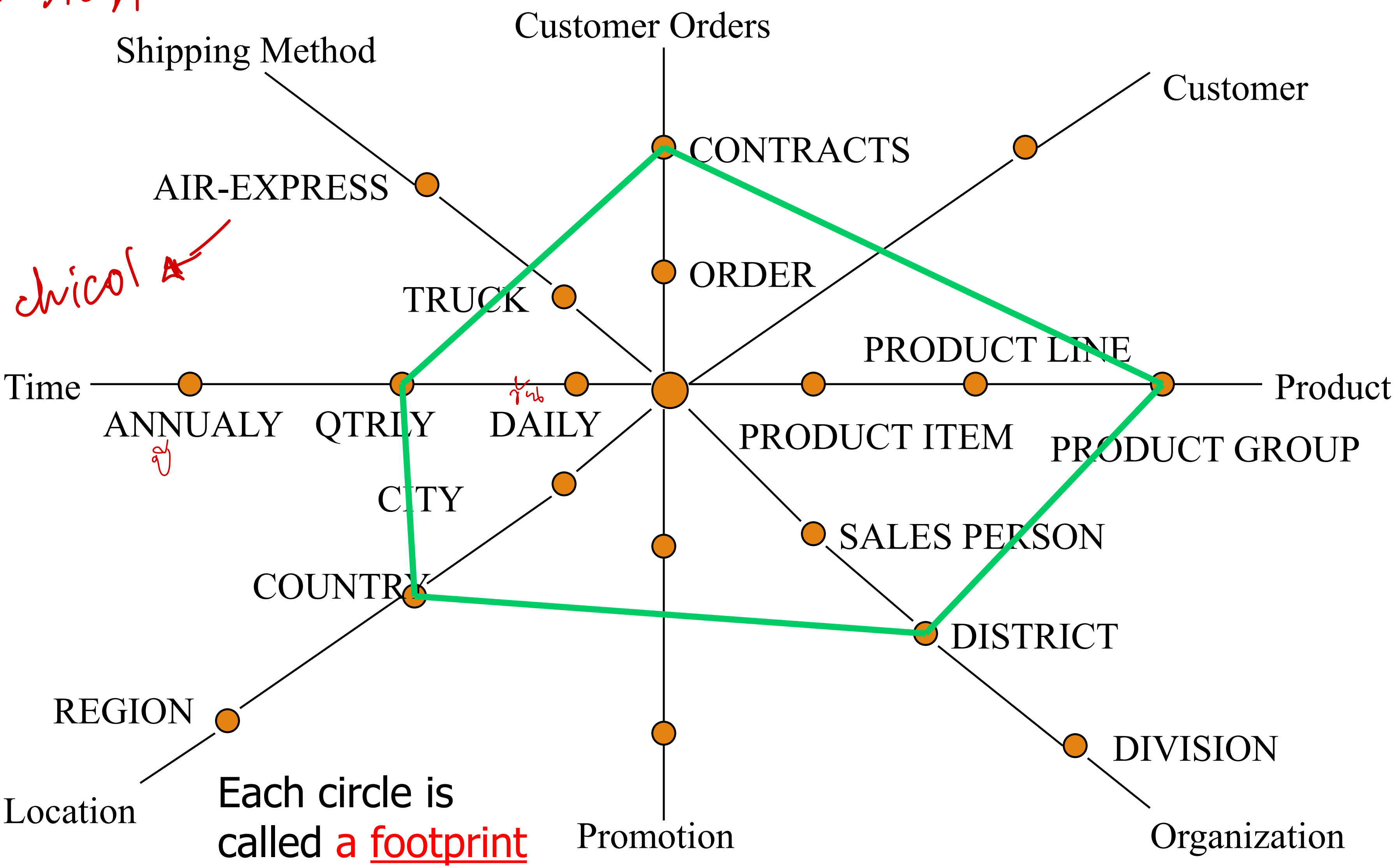


A Star-Net Query Model

ดูว่า data แตกย่อยลงไป ไรได้บ้าง

8 dimension

hierarchical



Each circle is called a footprint