Data Warehouse

——A Multi-dimensional data model——

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Data Model

- Review the basic concepts of database
- What is a data warehouse?
- A multi-dimensional data model
- Data warehouse architecture
- Data warehouse implementation
- From data warehousing to data mining

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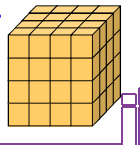
Data Cube (1)

- 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
  - Dimension tables (维表) , such as item (item_name, brand, type), or time(day, week, month, quarter, year)
  - Fact table （事实表） contains measures (such as dollars_sold) and keys to each of the related dimension tables
- In data warehousing literature, an n-D base cube is called a base cuboid(基本方体). The top most 0-D cuboid, which holds the highest-level of summarization, is called the apex cuboid(顶端方体). The lattice of cuboids forms a data cube.



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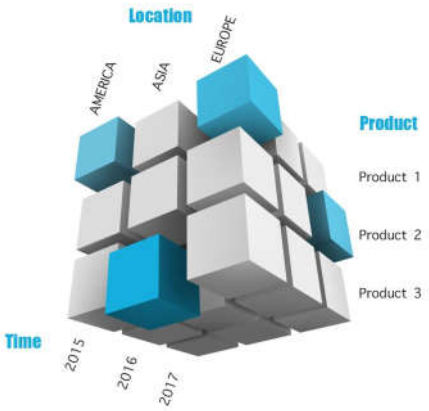
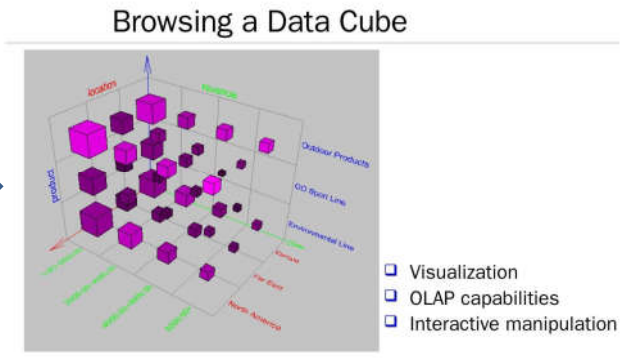
Data Cube (2)





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Data Cube (3)

- Dimension and Dimension table
  - Dimension: is the perspectives or entities with respect to which an organization wants to keep records.
  - Dimension table: is a set of properties to further describes a dimension.
- Each dimension may be associated with a dimension table.

  Time, item, location, provider
- Fact and fact table
  - Fact: the measure of a theme
  - Fact table: the representation of the fact. It contains the names of the facts, keys to each of the related dimension tables. Facts are numerical, sales amount

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Data Cube (4)

- Dimension number of data cube

  The number of dimensions to be viewed.

  Sales (item time location dollars_sold)

  Base cuboid: the cube which contains all dimensions that can be viewed in data warehousing.

  Apex cuboid: the cube which contain no dimension.

  Data Cube: is the all cuboids in a multi dimensional data model.

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Data Cube — One Example(1)

ALLElectronics sales

dimension : time , item , location , brand
dimension table :
time(time_key day day_of_week month quarter year)
item(item_key item_name brand type supplier_key)
fact table : (time_key item_key brand_key location_key dollars_sold units_sold)

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Data Cube — One Example(2)

2-dimension data cube:

location＝” Vancouver”

	item(type)		
Time(quarter)	**entertainment**	computer	security
Q1	605	825	400
Q2	680	920	512
Q3	781	1026	501
Q4	824	1120	580

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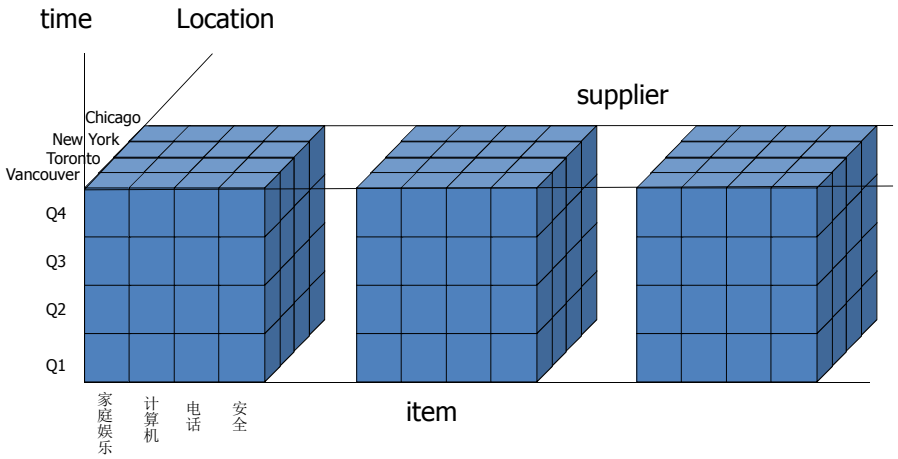
Data Cube — One Example(3)

- **4-dimension data cube**



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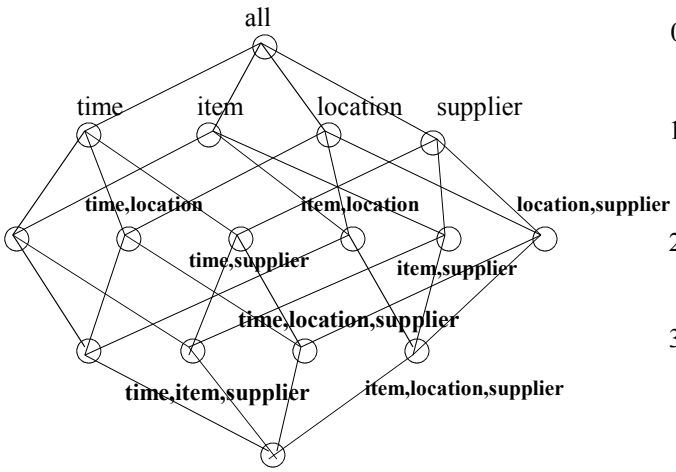
Cube: A Lattice of Cuboids



0-D(apex) cuboid

1-D cuboids

2-D cuboids

3-D cuboids

4-D(base) cuboid

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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 (事实星座): Multiple fact tables share dimension tables, viewed as a collection of stars, therefore called galaxy schema or fact constellation

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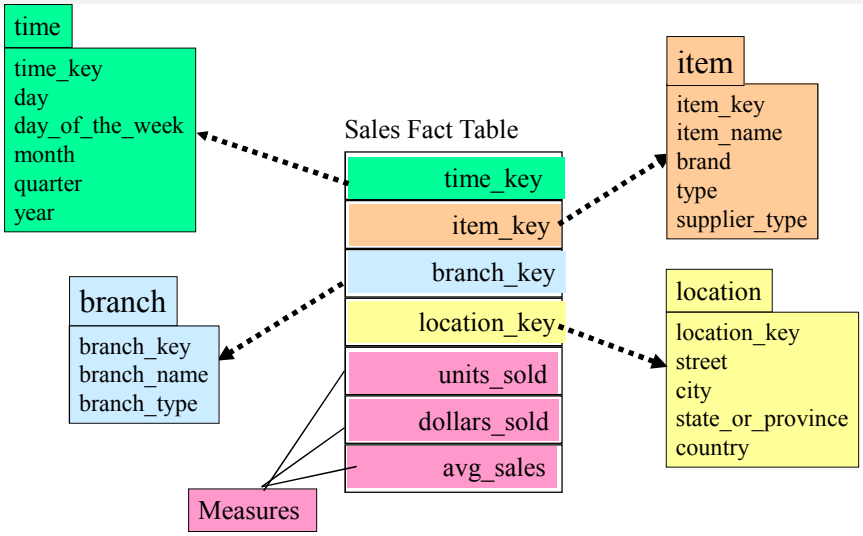
Example of Star Schema



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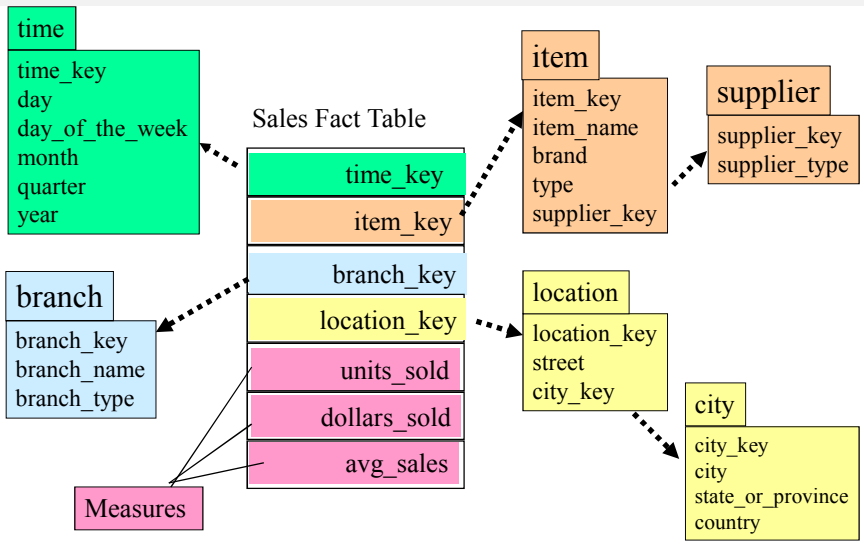
Example of Snowflake Schema



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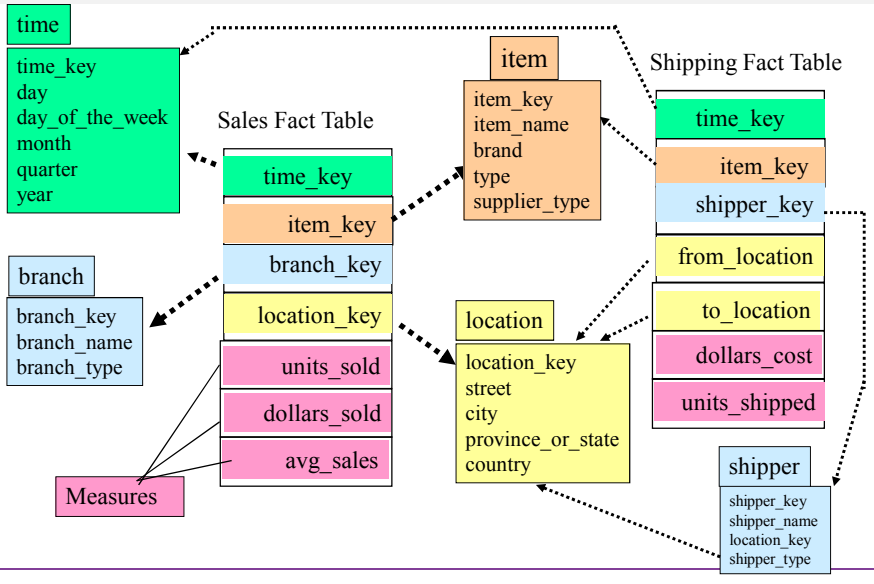
Example of Fact Constellations Schema



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Cube Definition Syntax (BNF) in DMQL

- **Cube Definition (Fact Table)**
  define cube <cube_name> [<dimension_list>]: <measure_list>
- **Dimension Definition (Dimension Table)**
  define dimension <dimension_name> as (<attribute_or_subdimension_list>)
- **Special Case (Shared Dimension Tables)**
  - First time as "cube definition"
  - define dimension <dimension_name> as <dimension_name_first_time> in cube <cube_name_first_time>

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Defining Star Schema in DMQL

define cube sales_star [time, item, branch, location]:

dollars_sold = sum(sales_in_dollars), avg_sales = avg(sales_in_dollars), units_sold = count(*)

define dimension time as (time_key, day, day_of_week, month, quarter, year)

define dimension item as (item_key, item_name, brand, type, supplier_type)

define dimension branch as (branch_key, branch_name, branch_type)

define dimension location as (location_key, street, city, province_or_state, country)

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Defining Snowflake Schema in DMQL

```
define cube sales_snowflake [time, item, branch, location]:
        dollars_sold = sum(sales_in_dollars), avg_sales = avg(sales_in_dollars), units_sold = count(*)
define dimension time as (time_key, day, day_of_week, month, quarter, year)
define dimension item as (item_key, item_name, brand, type, supplier(supplier_key,
   supplier_type))
define dimension branch as (branch_key, branch_name, branch_type)
define dimension location as (location_key, street, city(city_key, province_or_state,
   country))
```

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Defining Fact Constellation in DMQL

```
define cube sales [time, item, branch, location]:
        dollars_sold = sum(sales_in_dollars), avg_sales = avg(sales_in_dollars), units_sold = count(*)
define dimension time as (time_key, day, day_of_week, month, quarter, year)
define dimension item as (item_key, item_name, brand, type, supplier_type)
define dimension branch as (branch_key, branch_name, branch_type)
define dimension location as (location_key, street, city, province_or_state, country)
define cube shipping [time, item, shipper, from_location, to_location]:
        dollar_cost = sum(cost_in_dollars), unit_shipped = count(*)
define dimension time as time in cube sales
define dimension item as item in cube sales
define dimension shipper as (shipper_key, shipper_name, location as location in cube sales,
   shipper_type)
define dimension from_location as location in cube sales
define dimension to_location as location in cube sales
```

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A Concept Hierarchy: Dimension

- A concept hierarchy defines a sequence of mappings from a set of low-level concepts to higher-level, more general concepts.
  - categories:
    - the hierarchy of property: location, province, country
    - the hierarchy or grouping of property value
- For a given dimension, there may be more than one concept hierarchy.

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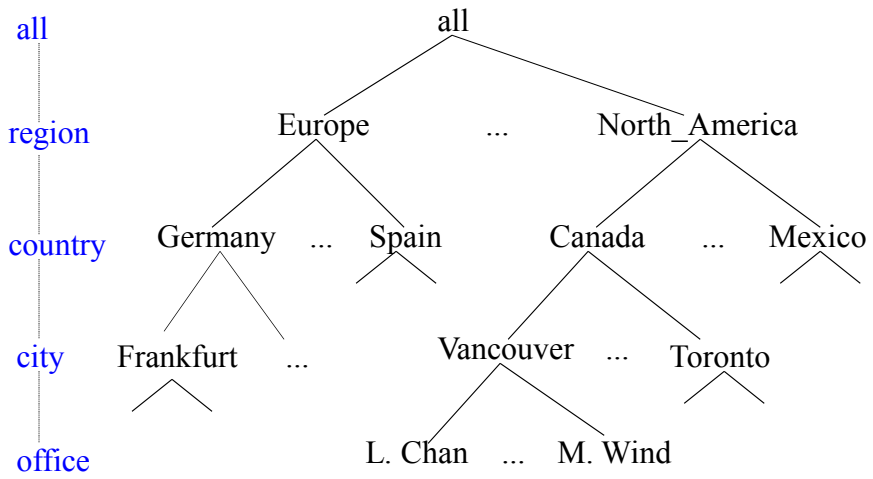
A Concept Hierarchy: Dimension (location)



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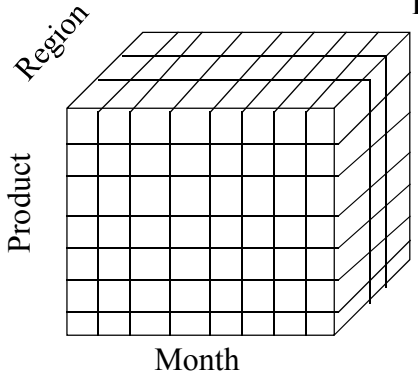
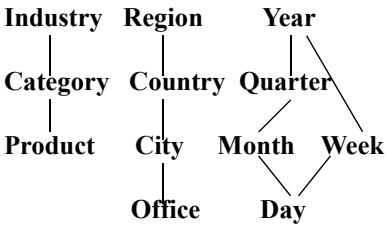
Multidimensional Data

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



Dimensions: Product, Location, Time
Hierarchical summarization paths



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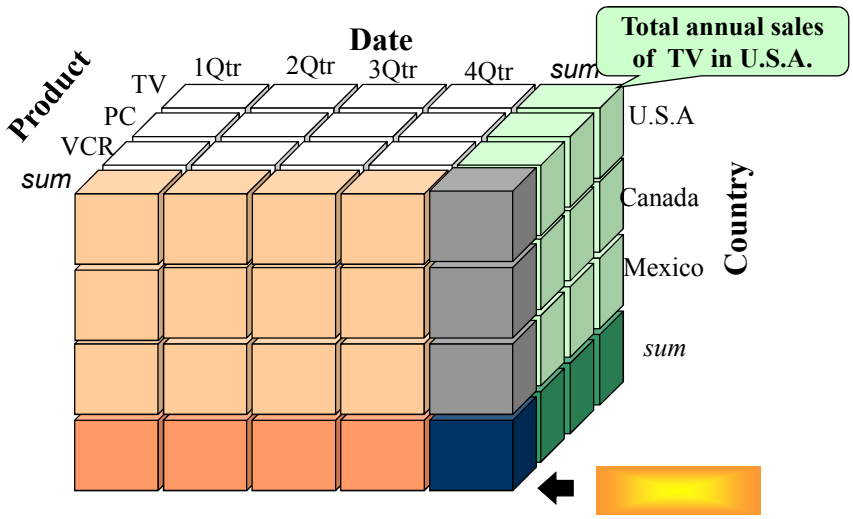
A Sample Data Cube



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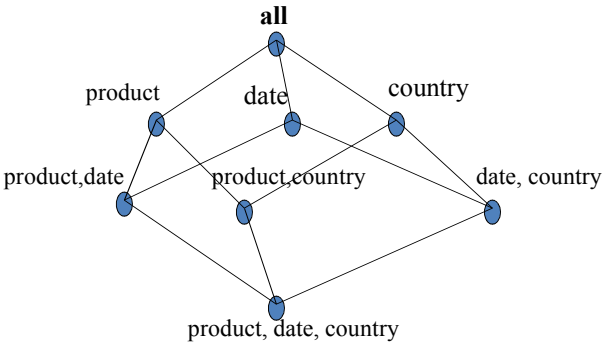
Cuboids Corresponding to the Cube



0-D(apex) cuboid

1-D cuboids

2-D cuboids

3-D(base) cuboid

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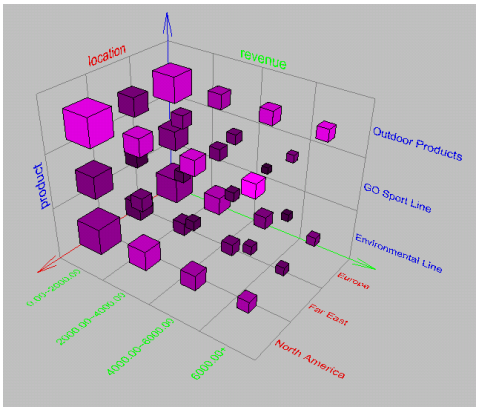
View of Warehouses and Hierarchies

- **Visualization**
- **OLAP capabilities**
- **Interactive manipulation**



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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 on one or more dimensions*
- **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)*

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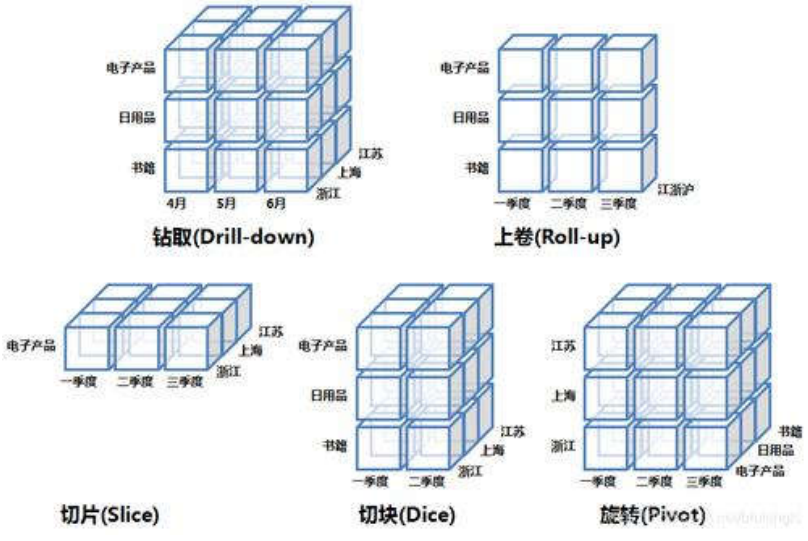
Typical OLAP Operations



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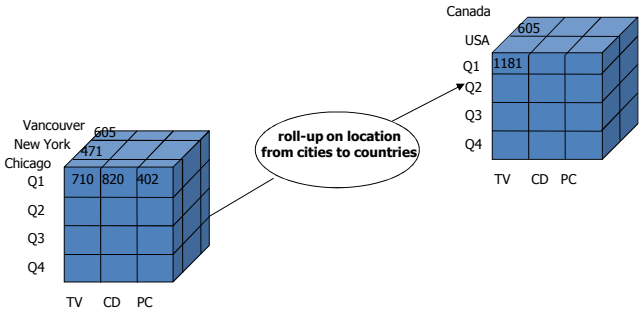
Typical OLAP Operations (1)

- **Roll up 上卷 (drill-up上钻):** summarize data
  - *by climbing up hierarchy (dimension reduction)*



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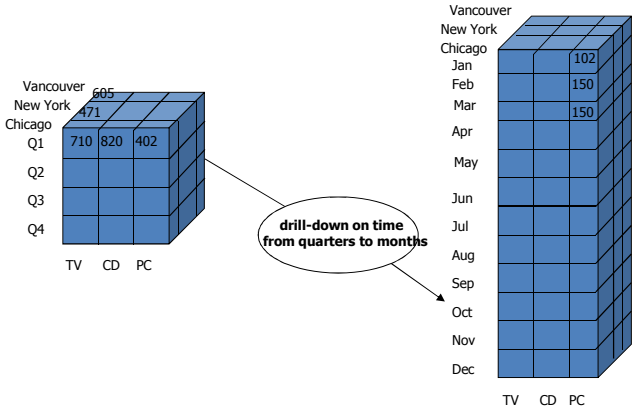
Typical OLAP Operations(2)

- **Roll down下卷 (Drill down下钻):** reverse of roll-up
  - *from higher level summary to lower level summary or detailed data, or introducing new dimensions*



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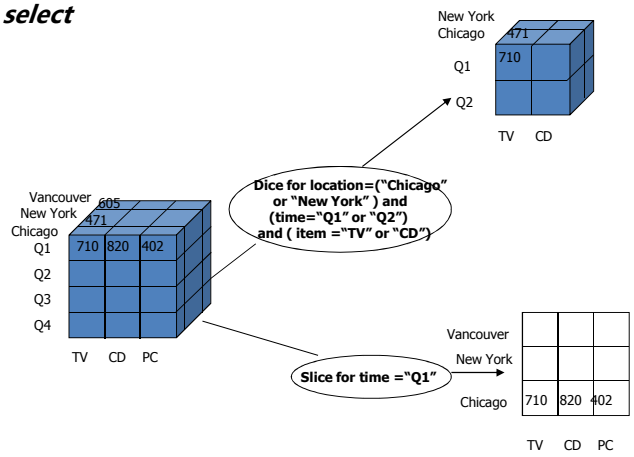
Typical OLAP Operations(3)

- **Slice(切片) and dice(切块):**
  - ***project and select***



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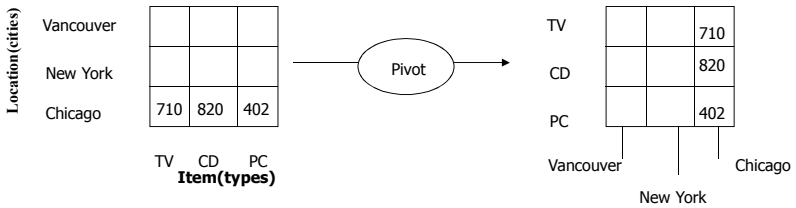
Typical OLAP Operations (4)

- **Pivot 旋转 (rotate旋转):**
  - ***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)**

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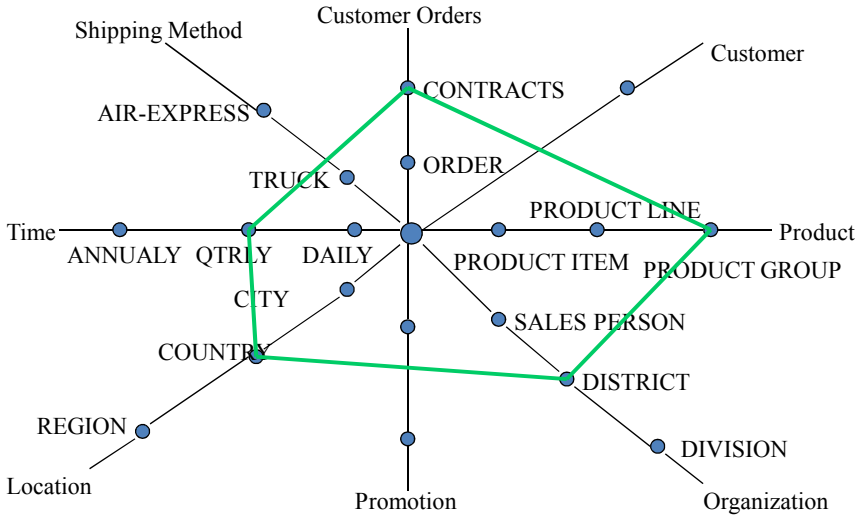
A Star-Net Query Model



Each circle is called a **footprint**.

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Thanks !

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