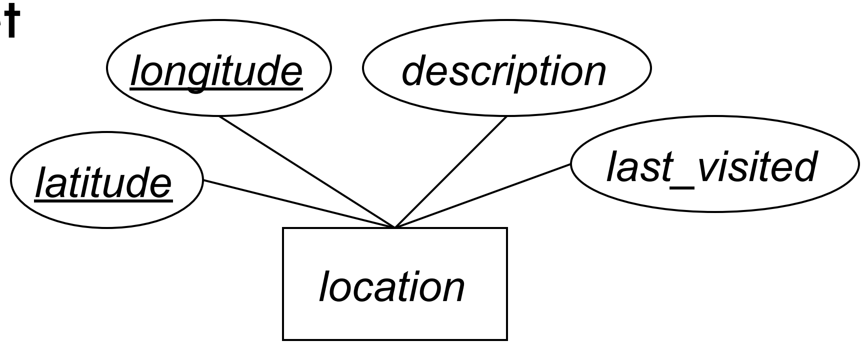
ALTERNATE SCHEMA DIAGRAMMING METHODS DECISION SUPPORT SYSTEMS

CS121: Introduction to Relational Database Systems

Fall 2014 – Lecture 23

E-R Diagramming

- E-R diagramming techniques used in book are similar to ones used in industry
  - Still, plenty of variation on how schemas are diagrammed
- Some books use a different diagramming technique
  - Attributes are represented as ovals attached to entity-set
  - Much harder to lay out!
  - Takes up a lot of room



- These methods don't include types or other constraints

Unified Modeling Language

- A standardized set of diagrams for specifying software systems
- Focuses on three major areas:
  - Functional requirements:
    - What is the system supposed to do?
    - Who may interact with the system, and what can they do?
  - Static structure:
    - What subsystems comprise the system?
    - What classes are needed, and what do they do?
  - Dynamic behavior:
    - What steps are taken to perform a given operation?
    - What is the flow of control through a system, and where are the decision points?

UML Class Diagrams

- UML class diagrams are typically used to diagram database schemas
  - Classes are similar to schemas
  - Objects are similar to tuples
- Two kinds of class diagrams for data modeling:
  - Logical data models (which are also called “E-R diagrams”)
    - Conceptual schema specification
    - Diagramming entity-sets and relationships, along the lines of the traditional E-R model, but not exactly like it
  - Physical data models
    - Implementation schema specification
    - Diagramming tables and foreign-key references
    - From a SQL perspective, is actually logical and view levels

UML Data Modeling

- Entity-sets and tables are represented as boxes
  - First line is entity-set name
  - Subsequent lines are attributes
  - First group of attributes usually the entity-set's primary key
    - Bolded, or marked with a *, +, or #
- Table diagrams often also include type details

location
latitude
longitude
description
last_visited

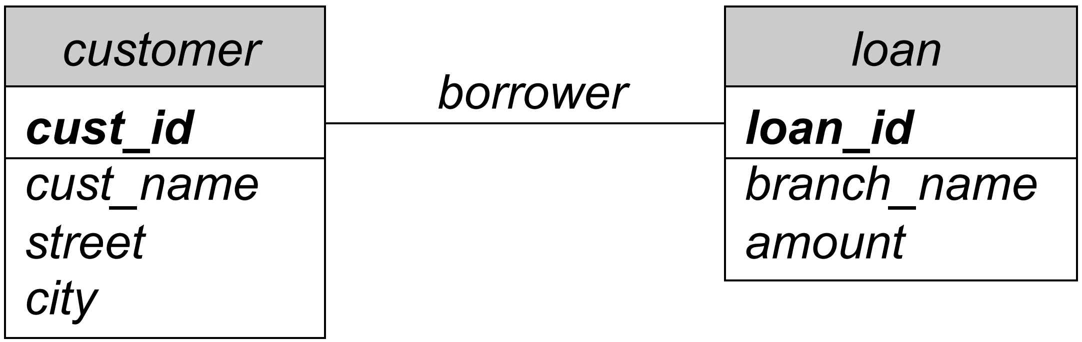
location	
latitude	NUMERIC(8, 5)
longitude	NUMERIC(8, 5)
description	VARCHAR(1000)
last_visited	TIMESTAMP

UML Relationships

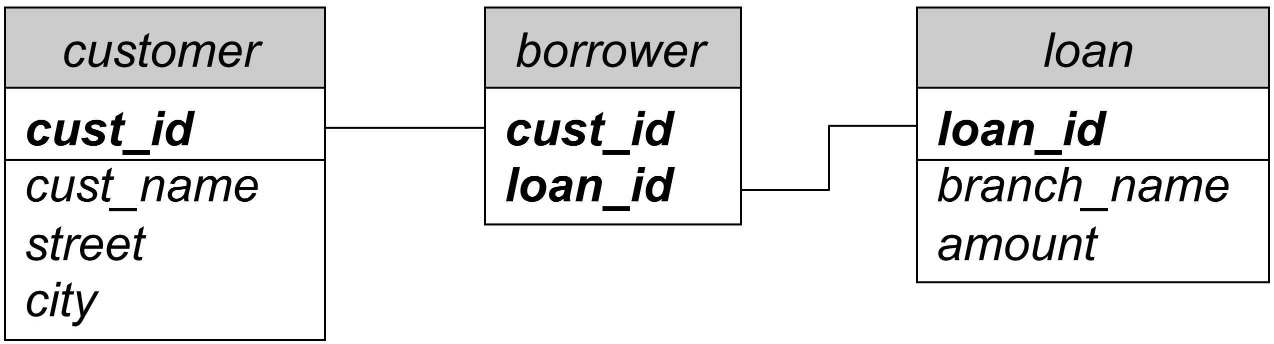
- Relationships are represented with a simple line
  - No diamond for the relationship
  - Relationship's name or role can be specified on line
- When modeling entity-sets (logical data model):
  - Don't include foreign-key columns
  - Foreign-key columns are implied by the relationship itself
- When modeling tables (physical data model):
  - Related tables actually include the foreign-key columns
  - Some relationships are modeled as separate tables
    - e.g. many-to-many relationships require a separate table

UML Relationship Examples

- Logical data model:

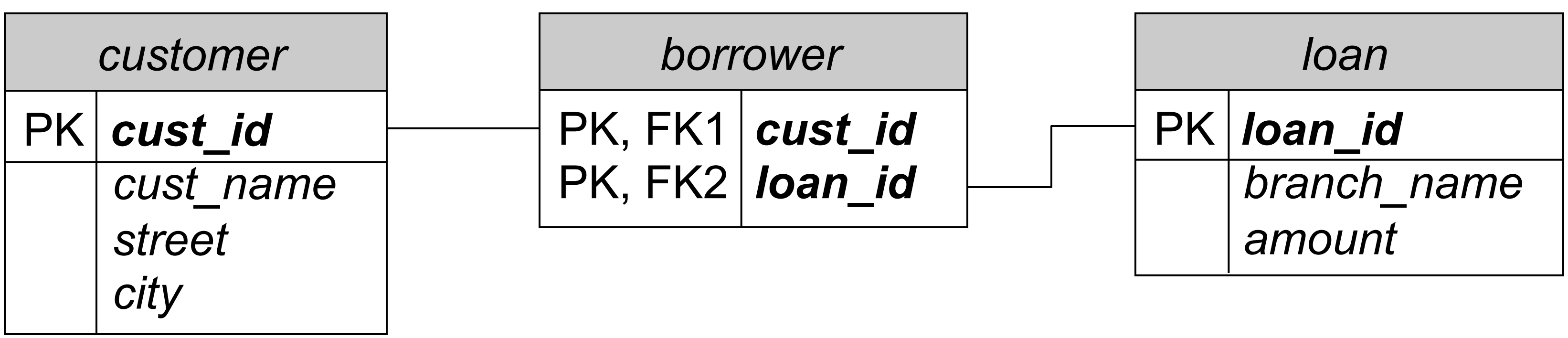


- Physical data model:
  - (would normally include type information too)



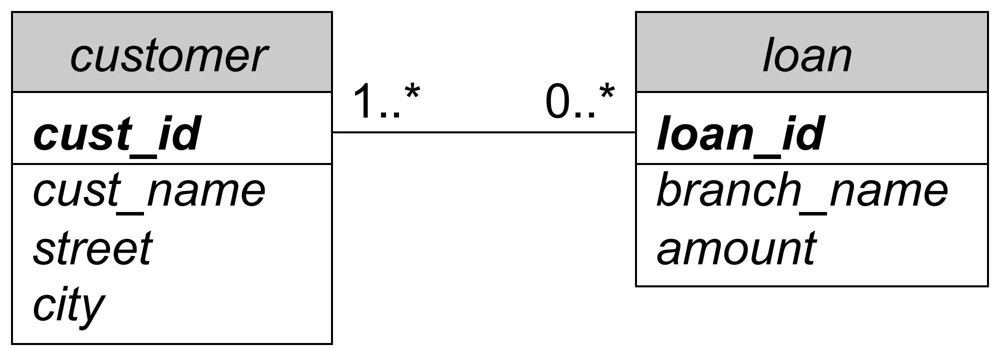
Annotating Keys

- Sometimes keys are indicated with two-character annotations
  - PK = primary key
  - FK = foreign key
- Candidate keys are specified with:
  - AK = alternate key
  - SK = surrogate key
    - (No difference between the two terms…)



Mapping Cardinalities

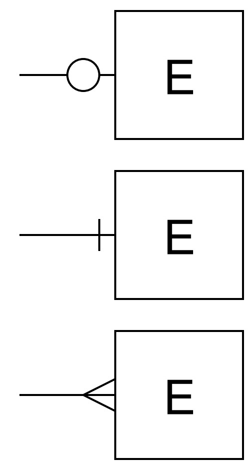
- Can specify numeric mapping constraints on relationships, just as in E-R diagrams
  - Can specify a single number for an exact quantity
  - lower..upper for lower and upper bounds
  - Use * for "many"

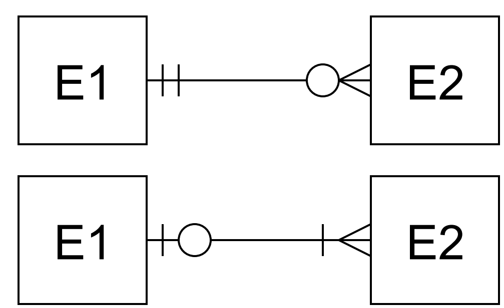


- Example:
  - Each customer is associated with zero or more loans
  - Each loan is associated with one or more customers

Information Engineering Notation

- Can also use Information Engineering Notation to indicate mapping cardinalities
  - Also called "crow's foot notation"
- Symbols:
  - Circle means "zero"
  - Line means "one"
  - Crow's foot means "many"
- Can combine symbols together
  - circle + line = "zero or one"
  - line + line = "exactly one"
  - line + crow's foot = "one or more"





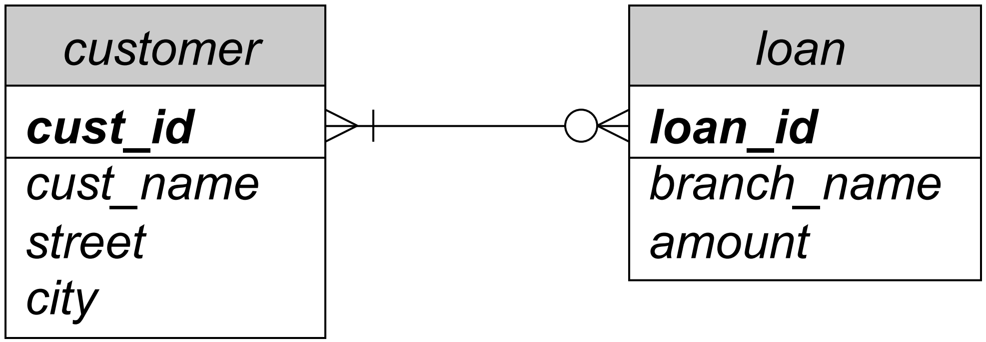
Barker's Notation

- A variant of Information Engineering Notation
- Symbols:
  - A solid line means "exactly one"
  - A dotted line means "zero or one"
  - Crow's foot + solid line means "one or more"
  - Crow's foot + dotted line means "zero or more"
- IE Notation:

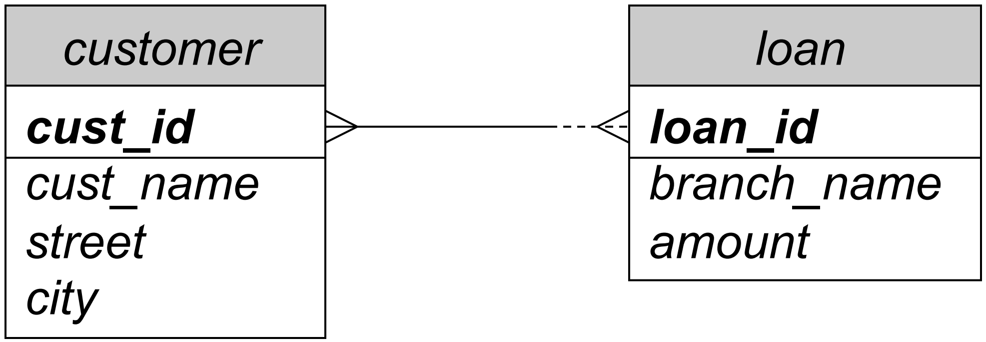
- Barker's Notation:

Examples

- Information Engineering notation:

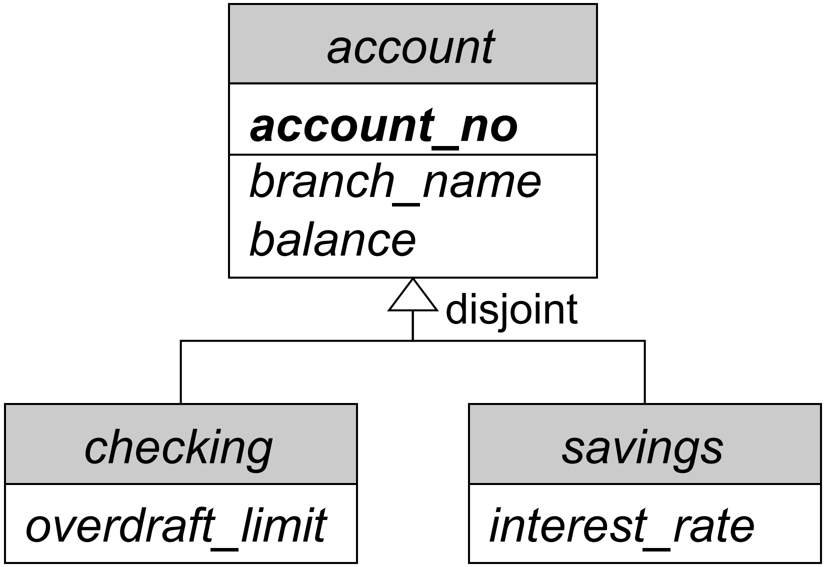


- Barker's notation:



Generalization and Specialization

- Can represent generalization in UML class diagrams
  - Open arrow, pointing from child to parent
- Can specify "disjoint" for disjoint specialization



UML Diagramming Summary

- <u>Very</u> good idea to learn UML diagramming!
  - Used extensively in the software industry
  - You can create visual diagrams of software, and other people will actually understand you! ☺
- Significant variation in details of how <u>data models</u> are diagrammed
  - Data modeling is *still* not yet a standard part of UML specification
  - Good to be familiar with all major techniques

OLTP and OLAP Databases

- OLTP: Online Transaction Processing
  - Focused on many short transactions, involving a small number of details
  - Database schemas are normalized to minimize redundancy
  - Most database applications are OLTP systems
- OLAP: Online Analytic Processing
  - Focused on analyzing patterns and trends in very large amounts of data
  - Database schemas are denormalized to facilitate better processing performance

Decision Support Systems

- Decision Support Systems (DSS) facilitate analyzing trends in large amounts of data
  - DSS don't actually identify the trends themselves
  - Are a tool for analysts familiar with what the data means
  - Analyze collected data to measure effectiveness of current strategies, and to predict future trends
  - Increasingly common for analysts to use data mining on a system to identify patterns and trends, too
- Decision support systems must provide:
  - Specific kinds of summary data generated from the raw input data
  - Ability to break down summary data along different dimensions, e.g. time interval, location, product, etc.

Decision Support Systems (2)

- OLAP databases are frequently part of decision support systems
  - Called data warehouses
  - Capable of storing, summarizing, and reporting on *huge* amounts of data
- Example data-sets presented via DSS:
  - Logs from web servers or streaming media servers
  - Sales records for a large retailer
  - Banner ad impressions and click-throughs
  - Very large data sets (frequently into petabyte range)
- Need to:
  - Generate summary information from these records
  - Facilitate queries against the summarized data

DSS Databases

- Example: sales records for a large retailer
  - Customer ID, time of sale, sale location
  - Product name, category, brand, quantity
  - Sale price, discounts or coupons applied
- Billions of sales records to process
  - Summary results may also include millions/billions of rows!
- Could fully normalize the database schema…
  - Information being analyzed and reported on would be spread through multiple tables
  - Analysis/reporting queries would require many joins
  - Often imposes a *heavy* performance penalty
- This approach is prohibitive for such systems!

Example Data Warehouses

- Starbucks figures from 2007:
  - 5TB data warehouse, growing by 2-3TB/year
- Wal-Mart figures from 2006:
  - 4PB data warehouse
- eBay figures from 2009:
  - Two data warehouses
  - Data warehouse 1: Teradata system
    - >2PB of user data
  - Data warehouse 2: Greenplum system
    - 6.5PB of user data
    - 17 trillion records – 150 billion new records each day
    - >50TB added each day

Measures and Dimensions

- Analysis queries often have two parts:
- A <u>measure</u> being computed:
  - "What are the total sales figures…"
  - "How many customers made a purchase…"
  - "What are the most popular products…"
- A <u>dimension</u> to compute the result over:
  - "…per month over the last year?"
  - "…at each sales location?"
  - "…per brand that we carry?"

Star Schemas

- Decision support systems often use a <u>star schema</u> to represent data
  - A *very* denormalized representation of data that is well suited to large-scale analytic processing
- One or more <u>fact tables</u>
  - Contain actual measures being analyzed and reported on
- Multiple <u>dimension tables</u>
  - Provide different ways to "slice" the data in the fact tables
- Fact tables have foreign-key references to the dimension tables

Example Star Schema

- Sales data-warehouse for a large retailer:

sale_dates
date_id
year
quarter
month
mday
hour
…

sales_data
date_id
product_id
store_id
inventory_sold
total_revenue
…

products
product_id
category
brand
prod_name
prod_desc
price
…

stores
store_id
address
city
state
zipcode
…

- Fact table is center of star
  - Dimension tables are referenced by the fact table

Dimensional Analysis

- This approach is called <u>dimensional analysis</u>
- Good example of denormalizing a schema to improve performance
  - Using a fully normalized schema will produce confusing and horrendously slow queries
- Decompose schema into a fact table and several dimension tables
  - Queries become very simple to write, or to generate
  - Database can execute these queries very quickly

Dimension Tables

- Dimension tables are used to select out specific rows from the fact table
  - Dimension tables should contain only attributes that we want to summarize over
  - Dimension tables can easily have many attributes
- Dimension tables are usually <u>very</u> denormalized
  - Specific values are repeated in many different rows
  - Only in 1NF
- Example: *sale_dates* dimension table
  - Year, quarter, month, day, and hour are stored as separate columns
  - Each row also has a unique ID column

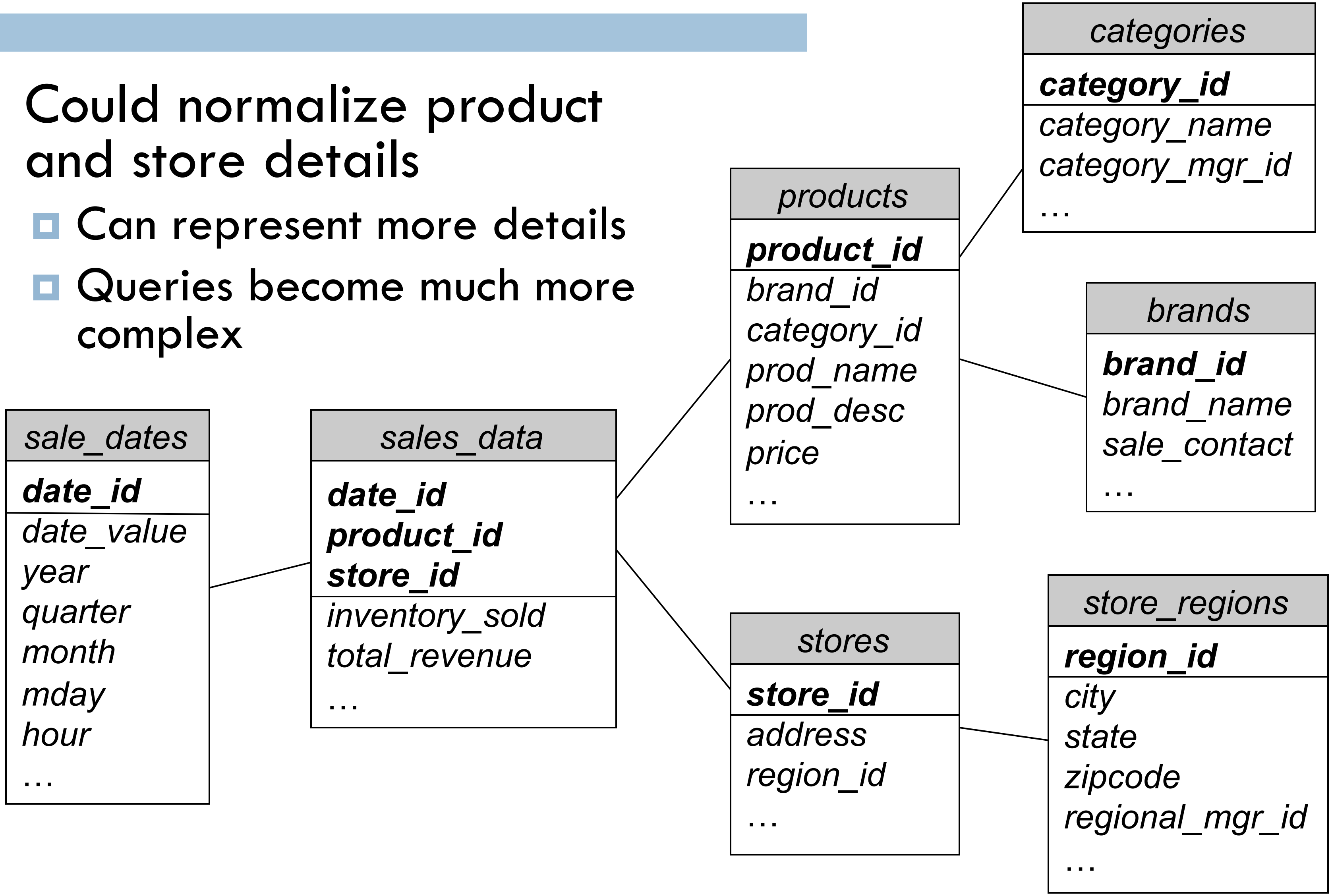
sale_dates
date_id
date_value
year
quarter
month
mday
hour
…

Dimension Tables (2)

- Dimension tables tend to be relatively small
  - At least, compared to the fact table!
  - Can be as small as a few dozen rows
  - All the way up to tens of thousands of rows, or more
    - Sometimes see dimension tables in 100Ks to millions of rows for very large data warehouses
- Sometimes need to normalize dimension tables
  - Eliminate redundancy to reduce size of dimension table
  - Increases complexity of query formulation and processing
  - Yields a <u>snowflake schema</u>
  - Star schemas *strongly* preferred over snowflake schemas, unless absolutely unavoidable!

Example Snowflake Schema

- Could normalize product and store details
  - Can represent more details
  - Queries become much more complex



Fact Tables

- Fact tables store aggregated values for the smallest required granularity of each dimension
  - Time dimension frequently drives this granularity
    - e.g. “daily measures” or “hourly measures”
- Fact tables tend to have fewer columns
  - Only contains the actual facts to be analyzed
  - Dimensional data is pushed into dimension tables
  - Each fact refers to its associated dimension values using foreign keys
  - All foreign keys in the fact table form its primary key
- Fact table contains the most rows, by far.
  - Well upwards of millions of rows (billions/trillions common)

Fact Tables (2)

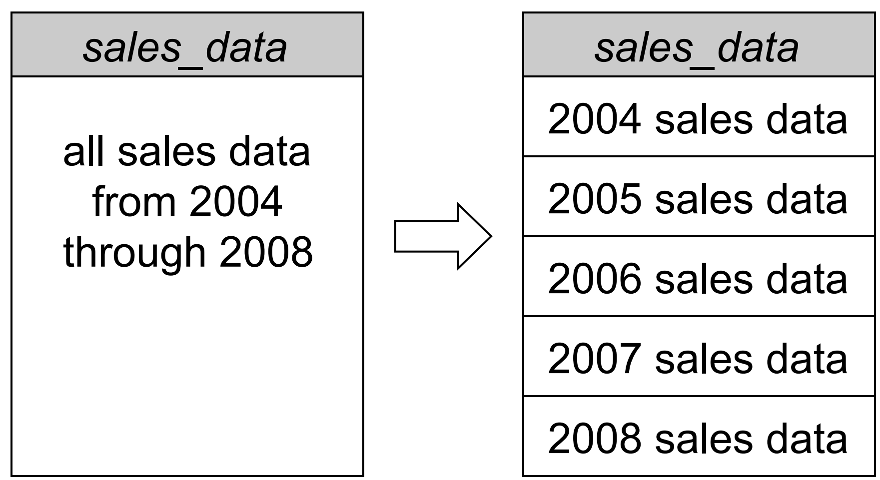
- Not uncommon to have multiple fact tables in a data warehouse
  - Facts relating to different aspects of the enterprise, where it doesn't make sense to store in same table
  - Facts for a single aspect of the enterprise, but partitioned in different ways
    - Used in situations where combining into a single fact table would result in a huge, sparse fact table that is very slow to query
- Multiple fact tables frequently share dimension tables
  - e.g. date and/or time dimensions
  - May also have separate dimension tables only used by a particular fact-table

Analytic Queries

- Using a star schema, analytic queries follow a simple pattern
  - Query groups and filters rows from the fact table, using values in the dimension tables
  - Query performs simple aggregation of values contained within selected rows from fact table
- Queries contain only a few simple joins
  - Because dimension tables are (usually) small, joins can be performed very quickly
  - Fact table's primary key includes foreign keys to dimensions, so specific fact records can be located very quickly

Analytic Queries (2)

- Because only the fact tables are large, databases can provide optimized access
- Example: partitioned tables
  - Many databases can partition tables based on one or more attributes
  - Queries against the partitioned table are analyzed for which partitions are actually relevant to the query
- DSS schema design can partition the fact table to dramatically improve performance



Slowly-Changing Dimensions

- Frequently, data in dimension tables changes over time
  - e.g. a “user” dimension, where some user details change over time
    - e-mail address, rank/trust level within a community, last login time
- How do we represent slowly changing dimensions?
- Type 1 Slowly Changing Dimensions:
  - When a dimension value changes, overwrite the old values
  - Warehouse only maintains one row for each dimension value
  - Doesn’t track any history of changes to dimension records
    - Can’t analyze facts with respect to the change history!
    - e.g. “How do user behaviors change, with respect to how quickly their rank/trust level changes within their community?”

Slowly-Changing Dimensions (2)

- Type 2 Slowly Changing Dimensions:
  - Used to track change-history within a dimension
  - Rows in the dimension table are given additional attributes:
    - *start_date*, *end_date* – specifies the date/time interval when the values in this dimension record are valid
    - *version* – a count (e.g. starting from 0 or 1) indicating which version of the dimension record this row represents
    - *is_most_recent* – a flag indicating whether this is the most recent version of the dimension record
- Updating a dimension record is more complicated:
  - Find current version of the dimension record (if there is one)
  - Set the *end_date* to "now" to indicate the old row is finished
  - Create a new dimension record with a *start_date* of "now"
    - Fill in new dimension values; update *version*, *is_most_recent* values too

Good and Bad Measures

- Not all measures are suitable for star schemas!
- Fact table contains *partially* aggregated results
  - Analysis queries must complete aggregation, based on desired dimension and grouping aspects of query
- Example measures to track:
  - Quantities of each product sold
    - Easy to aggregate – just sum it up
  - Average per-customer sales totals
    - Fact table needs to store both the number of sales, and the total sale price, so that query can compute the average
  - Distinct customers over a particular time interval
    - Would need to store a list of actual customer IDs for each reporting interval! Much more complex.

Homework 7

- Includes a very simple data-warehouse exercise:
  - A simple OLAP database for analyzing web logs
    - Two months of access logs from NASA web server at Kennedy Space Center in Florida, from 1995
    - 3.6 million records, about 300MB storage size
    - Huge compared to what we have worked with so far!
    - Microscopic compared to most OLAP databases ☺
  - Create an OLAP database schema
    - Star schema diagram will be provided
  - Populate the schema from raw log data
  - Write some OLAP queries to do some simple analysis
- Please start this assignment early!
  - 100 students vs. 1 DB server… it could get messy… ☺