ICS 101 Fall 2012

Introduction to Data Management

Asst. Prof. Lipyeow Lim

Information & Computer Science Department

University of Hawaii at Manoa

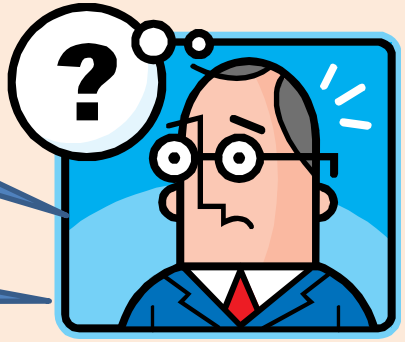
The Data Management Problem

Where is the photo I took last Christmas ?

Where did I read about "Turing Machines" ?

Where is the invoice for this computer ?

Which product is the most profitable ?



User

Queries

?

Data

What is ``data'' ?

- **Data** are known facts that can be recorded and that have implicit meaning.
- Three broad categories of data
  - Structured data
  - Semi-structured data
  - Unstructured data
- ``Structure'' of data refers to the organization within the data that is identifiable.

What is a database ?

- A **database** : a collection of related data.
  - Represents some aspect of the real world (aka universe of discourse).
  - Logically coherent collection of data
  - Designed and built for specific purpose
- A **data model** is a collection of concepts for describing/organizing the data.
- A **schema** is a description of a particular collection of data, using the a given data model.

The Relational Data Model

- *Relational database:* a set of *relations*
- A *relation* is made up of 2 parts:
  - *Instance* : a *table*, with rows and columns. #Rows = *cardinality*, #fields = *degree / arity.*
  - *Schema* : specifies name of relation, plus name and domain/type of each column or attribute.
    - E.G. Students(sid: string, name: string, login: string, age: integer, gpa: real).
- Can think of a relation as a *set* of rows or *tuples* (i.e., all rows are distinct).

Example Instance of Students Relation

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

- Cardinality = 3, degree=5, all rows distinct

Why is the relational model useful ?

- Supports simple and powerful query capabilities!
- Structured Query Language (SQL)

```
SELECT S.sname
FROM  Students S
WHERE  S.gpa>3.5
```

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

What is a DBMS ?

- A **database management system (DBMS)** is a *collection of programs* that enables users to
  - Create new DBs and specify the structure using data definition language (DDL)
  - Query data using a query language or data manipulation language (DML)
  - Store very large amounts of data
  - Support durability in the face of failures, errors, misuse
  - Control concurrent access to data from many users

Types of Databases

- On-line Transaction Processing (OLTP)
  - Banking
  - Airline reservations
  - Corporate records
- On-line Analytical Processing (OLAP)
  - Data warehouses, data marts
  - Business intelligence (BI)
- Specialized databases
  - Multimedia
  - XML
  - Geographical Information Systems (GIS)
  - Real-time databases (telecom industry)
- Special Applications
  - Customer Relationship Management (CRM)
  - Enterprise Resource Planning (ERP)
- Hosted DB Services
  - Amazon, Salesforce

A Bit of History

- 1970 Edgar F Codd (aka "Ted") invented the relational model in the seminal paper "A Relational Model of Data for Large Shared Data Banks"
  - Main concept: *relation* = a table with rows and columns.
  - Every relation has a *schema*, which describes the columns.
- Prior 1970, no standard data model.
  - Network model used by Codasyl
  - Hierarchical model used by IMS
- After 1970, IBM built System R as proof-of-concept for relational model and used **SQL** as the query language. SQL eventually became a standard.

Why use a DBMS ?

- Large datasets
- Concurrency/ multi-user
- Crash recovery
- Declarative query language
- No need to figure out what low level data structure
- Data independence and efficient access.
- Reduced application development time.
- Data integrity and security.
- Uniform data administration.

Transactions

- A *transaction* is the DBMS's abstract view of a user program: a sequence of reads and writes.
  - Eg. User 1 views available seats and reserves seat 22A.
- A DBMS supports multiple users, ie, multiple transactions may be running concurrently.
  - Eg. User 2 views available seats and reserves seat 22A.
  - Eg. User 3 views available seats and reserves seat 23D.

ACID Properties of Transactions

- **A**tomicity : all-or-nothing execution of transactions
- **C**onsistency: constraints on data elements is preserved
- **I**solation: each transaction executes as if no other transaction is executing concurrently
- **D**urability: effect of an executed transaction must never be lost

Atomicity

- A transaction might *commit* after completing all its actions, or it could *abort* (or be aborted by the DBMS) after executing some actions.
- A very important property guaranteed by the DBMS for all transactions is that they are *atomic*. That is, a user can think of a Xact as always executing all its actions in one step, or not executing any actions at all.
  - DBMS *logs* all actions so that it can *undo* the actions of aborted transactions.

Example (Atomicity)

```
T1:     BEGIN
        A=A+100
        B=B-100
        END
```

```
T2:     BEGIN
        A=1.06*A
        B=1.06*B
        END
```

- The first transaction is transferring $100 from B's account to A's account.
- The second is crediting both accounts with a 6% interest payment
- There is no guarantee that T1 will execute before T2 or vice-versa, if both are submitted together. However, the net effect must be equivalent to these two transactions running serially in some order.

Ensuring Isolation

- Scheduling concurrent transactions
- DBMS ensures that execution of {T1, ... , Tn} is equivalent to some *serial* execution T1' ... Tn'.

- Idea: use locks to serialize access to shared objects
- Strict 2 Phase locking protocol:
  - Before reading/writing an object, a transaction requests a lock on the object, and waits till the DBMS gives it the lock.
  - All locks are released at the end of the transaction.
  - What if Tj already has a lock on Y and Ti later requests a lock on Y? (Deadlock!) Ti or Tj is aborted and restarted!

Files vs DBMS

- Swapping data between memory and files
- Difficult to add records to files
- Security & access control
- Do optimization manually
- Good for small data/files
- Run out of pointers (32bit)
- Code your own search algorithm
  - Search on different fields is difficult
- Must protect data from inconsistency due to concurrency
- Fault tolerance – crash recovery

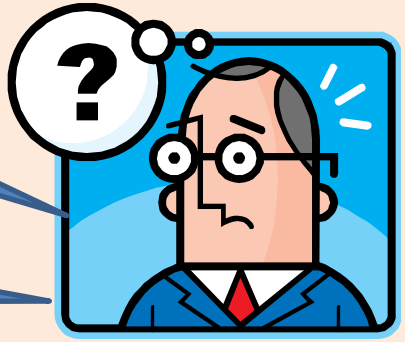
The Data Management Problem

Where is the photo I took last Christmas ?

Where did I read about "Turing Machines" ?

Where is the invoice for this computer ?

Which product is the most profitable ?



User

Queries

?

Data

Unstructured Data

- What are some examples of unstructured data?
- How do we model unstructured data ?
- How do we query unstructured data ?
- How do we process queries on unstructured data ?
- How do we index unstructured data ?

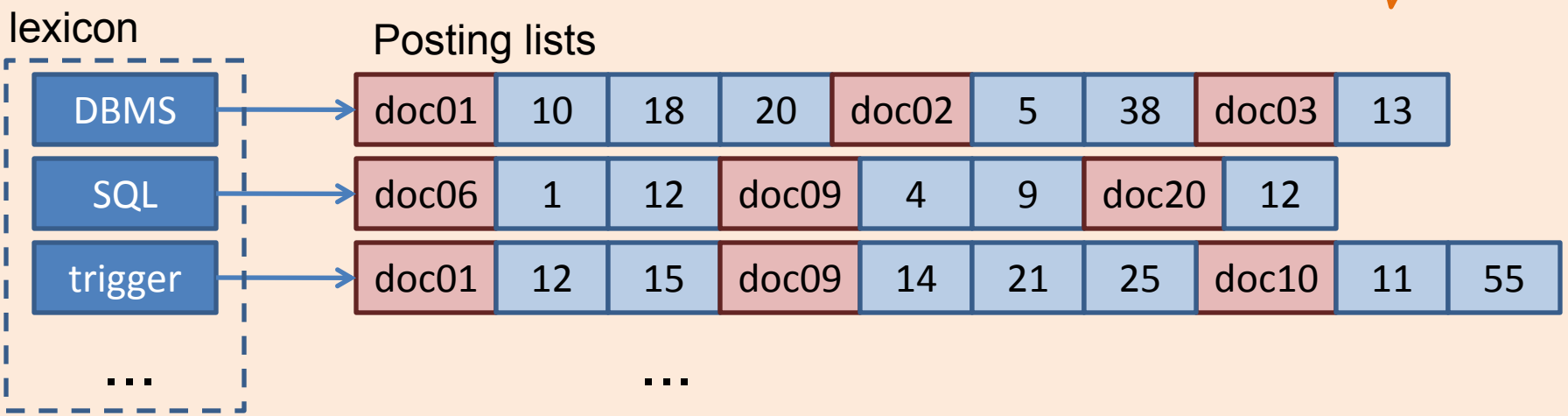
Unstructured Text Data

- Field of "Information Retrieval"
- Data Model
  - Collection of documents
  - Each document is a bag of words (aka terms)
- Query Model
  - Keyword + Boolean Combinations
  - Eg. DBMS and SQL and tutorial
- Details:
  - Not all words are equal. "Stop words" (eg. "the", "a", "his" ...) are ignored.
  - Stemming : convert words to their basic form. Eg. "Surfing", "surfed" becomes "surf"

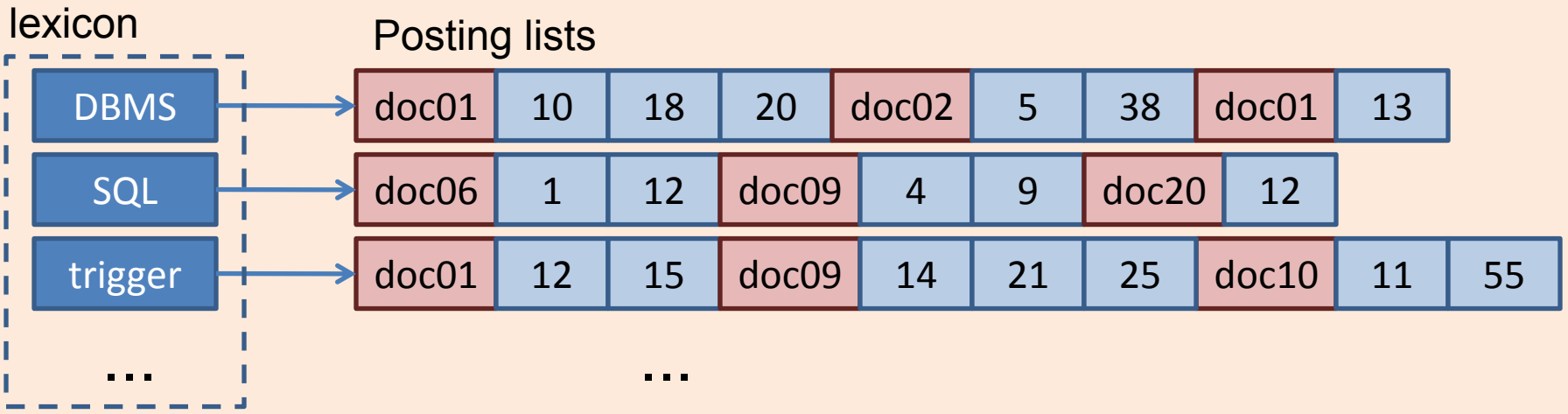
Inverted Indexes

- Recall: an index is a mapping of search key to data entries
  - What is the search key ?
  - What is the data entry ?
- Inverted Index:
  - For each term store a list of postings
  - A posting consists of <docid,position> pairs

What is the data in an inverted index sorted on ?



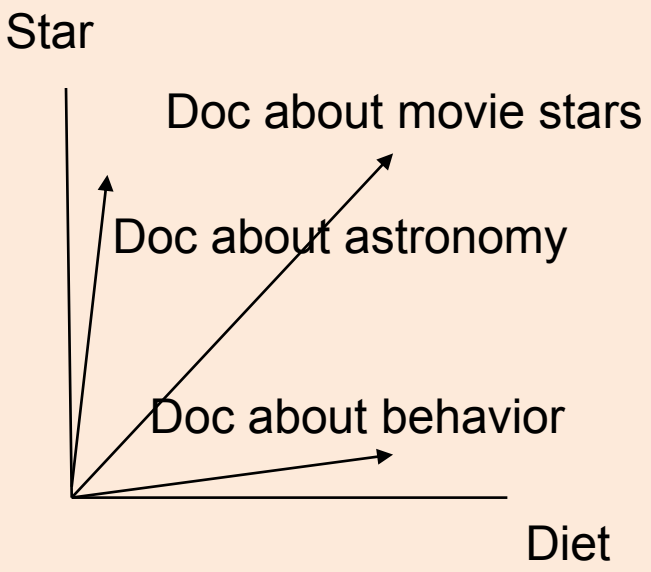
Lookups using Inverted Indexes



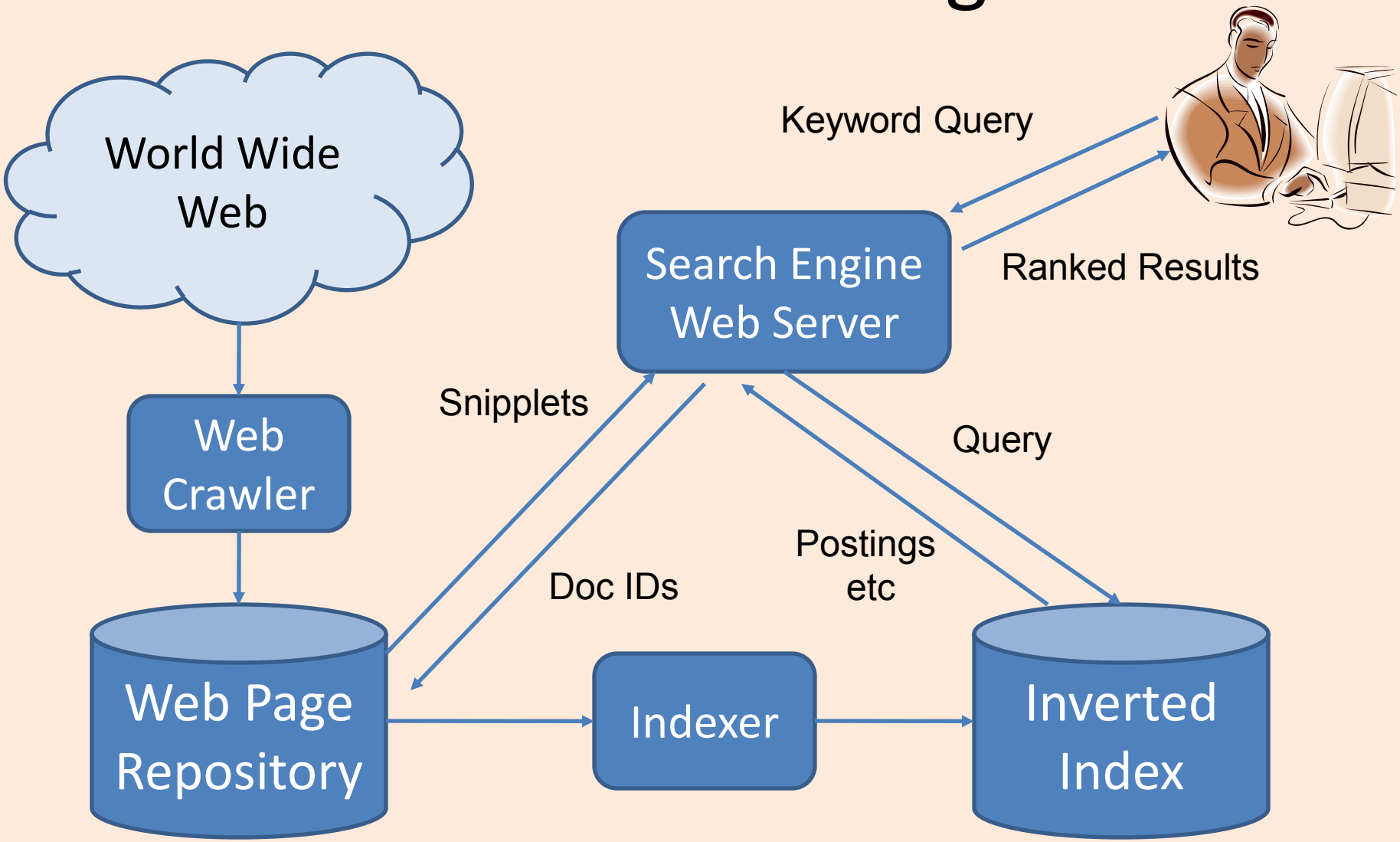
- Given a single keyword query "k" (eg. SQL)
  - Find k in the lexicon
  - Retrieve the posting list for k
  - Scan posting list for document IDs [and positions]
- What if the query is "k1 and k2" ?
  - Retrieve document IDs for k1 and k2
  - Perform intersection

Too Many Matching Documents

- Rank the results by “relevance”!
- Vector-Space Model
  - Documents are vectors in hi-dimensional space
  - Each dimension in the vector represents a term
  - Queries are represented as vectors similarly
  - Vector distance (dot product) between query vector and document vector gives ranking criteria
  - Weights can be used to tweak relevance
- PageRank (later)



Internet Search Engines



Basic Web Search

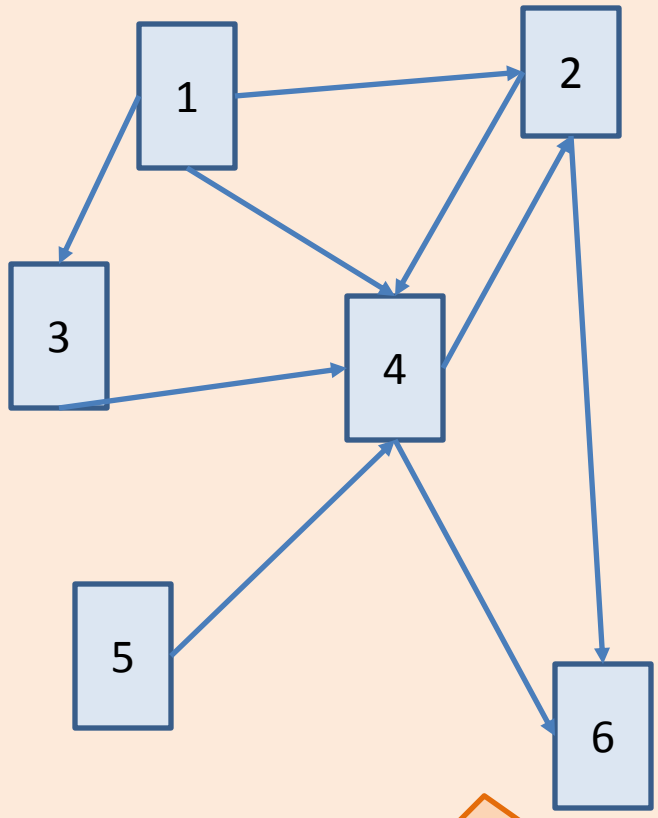
- http://www.googleguide.com/advanced_operators_reference.html

Query Expression	What it means
Biking italy	Biking **AND** italy
Recycle steel OR iron	Recycle **AND** (steel **OR** iron)
“I have a dream”	“I have a dream” treated as one term
Salsa -dance	Salsa **AND NOT** dance

Other nifty expressions	What it means
12 + 34 - 56 * 7 / 8	Evaluates the arithmetic expression
300 Euros in USD	Converts 300 euros to US currency

Ranking Web Pages

- Google's PageRank
  - Links in web pages provide clues to how important a webpage is.
- Take a random walk
  - Start at some webpage p
  - Randomly pick one of the links and go to that webpage
  - Repeat for all eternity
- The number of times the walker visits a page is an indication of how important the page is.



Vertices represent web pages.
Edges represent web links.

Semi-structured Search

Web pages are not really unstructured! Click “view source” to view HTML.

Query Expression	What it means
define:imbroglio	Find definitions of “imbroglio”
Halloween **site:**www.census.gov	Restrict search for “halloween” to US census website
Form 1098-T IRS **filetype:**pdf	Find the US tax form 1098-T in PDF format
link:warriorlibrarian.com	Find pages that link to Warrior Librarian's website
Dan Shugar **intext:**Powerlight	Find pages mentioning **Dan Shugar** where his company, **Powerlight**, is included in the text of the page, i.e., less likely to be from the corporate website.
allintitle: Google Advanced Operators	Search for pages with titles containing "Google," "Advanced,", and "Operators"

Summary

- Data Management Problem
  - How do we pose and answer queries on data?
- Structured data
  - Relational Data Model
  - SQL
  - Relational DBMS
  - Transactions
- Unstructured data
  - Bag of terms
  - Boolean combination of keyword queries
  - Inverted Indexes (Web Search Engines)
- Semi-structured data
  - Could use techniques from either structured or unstructured
  - More sophisticated keyword queries