ICS 321 Data Storage & Retrieval

Other Data Models : Unstructured, Graph, Key-Value Pairs

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Outline

Unstructured Data and Inverted Indexes

Web Search Engines

RDF & Linking Open Data

Big Table, CouchDB, & Cassandra

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 ?

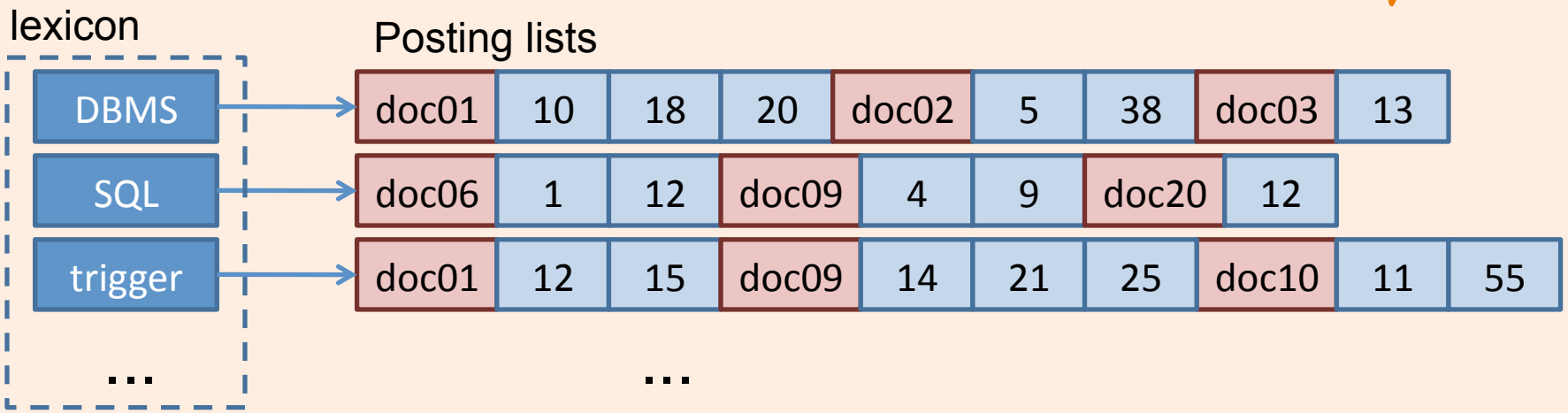
Unstructured Text Data

- 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"

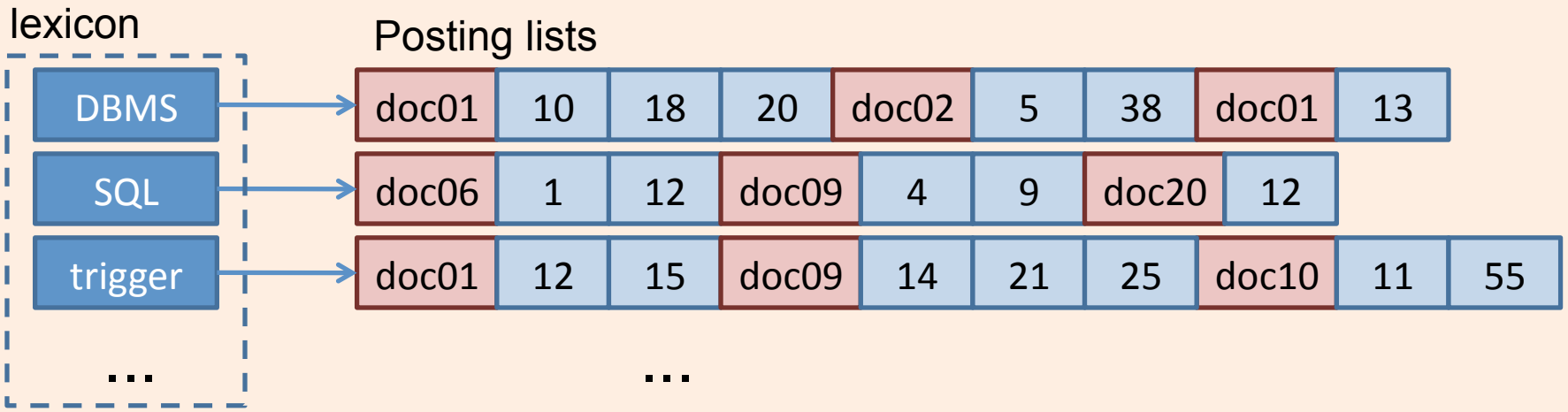
Inverted Indexes

- 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 ?



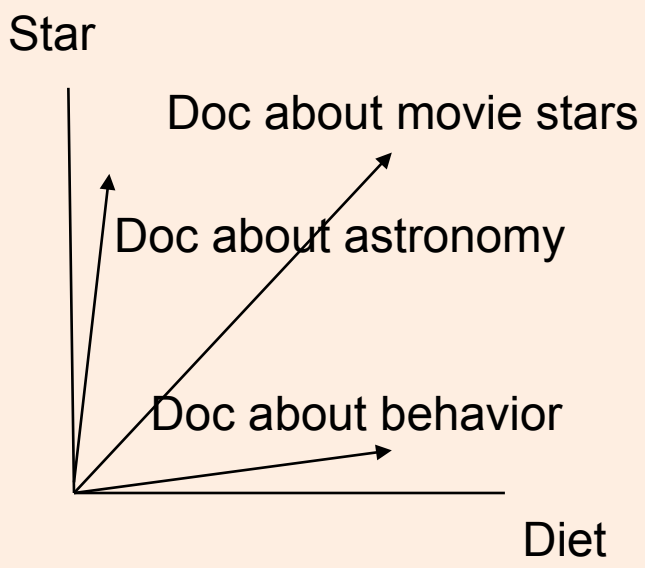
Lookups using Inverted Indexes



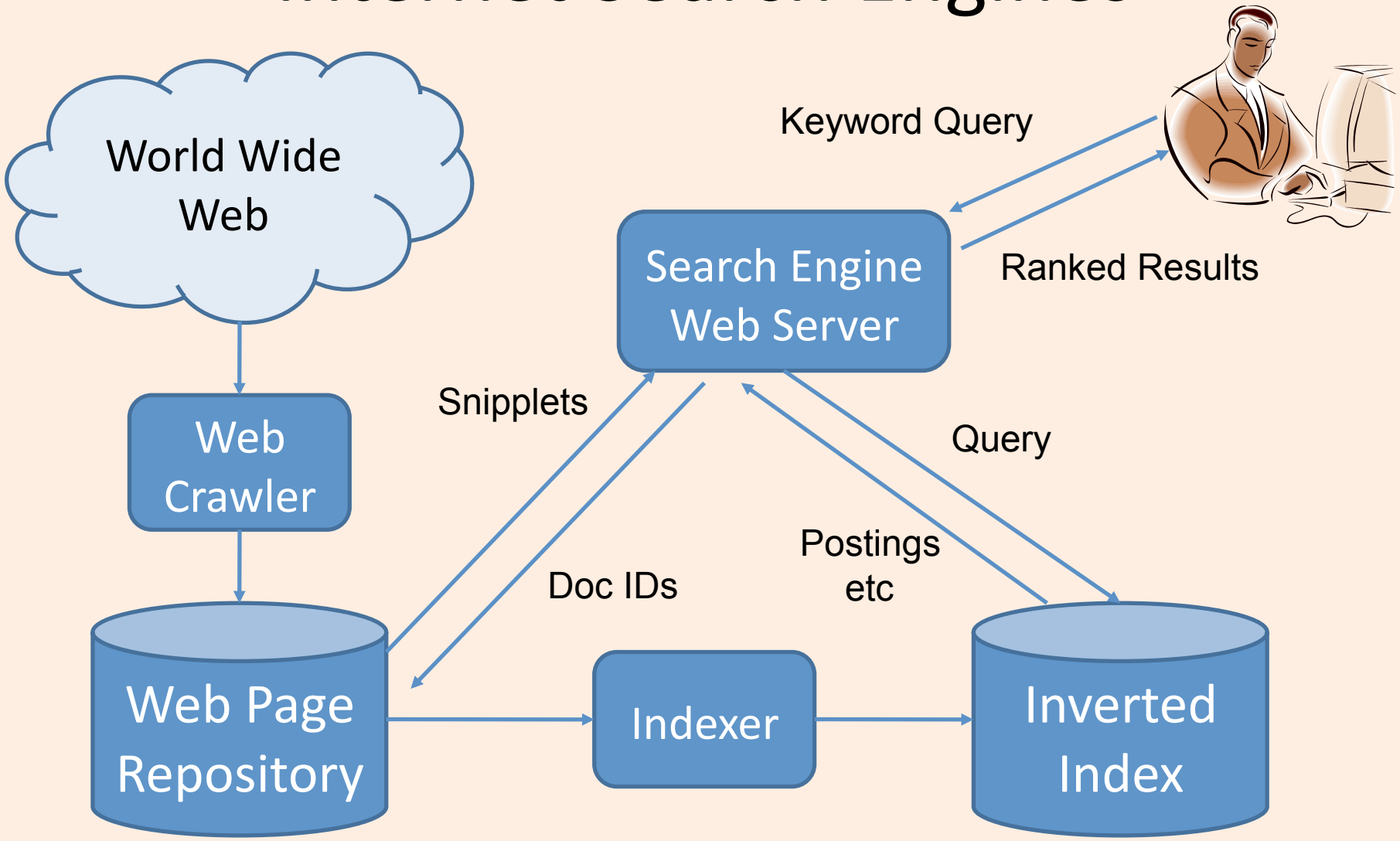
- Given a single keyword query "k" (eg. SQL)
  - Find k in the lexicon
  - Retrieve the posting list for k
  - Scan posting list for document IDs [and positions]
- What if the query is "k1 and k2" ?
  - Retrieve document IDs for k1 and k2
  - Perform intersection

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)

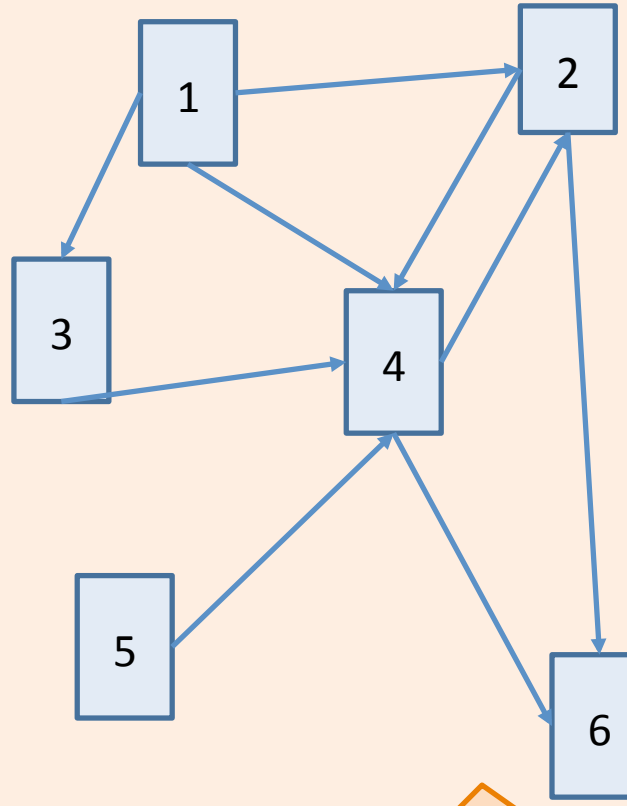


Internet Search Engines



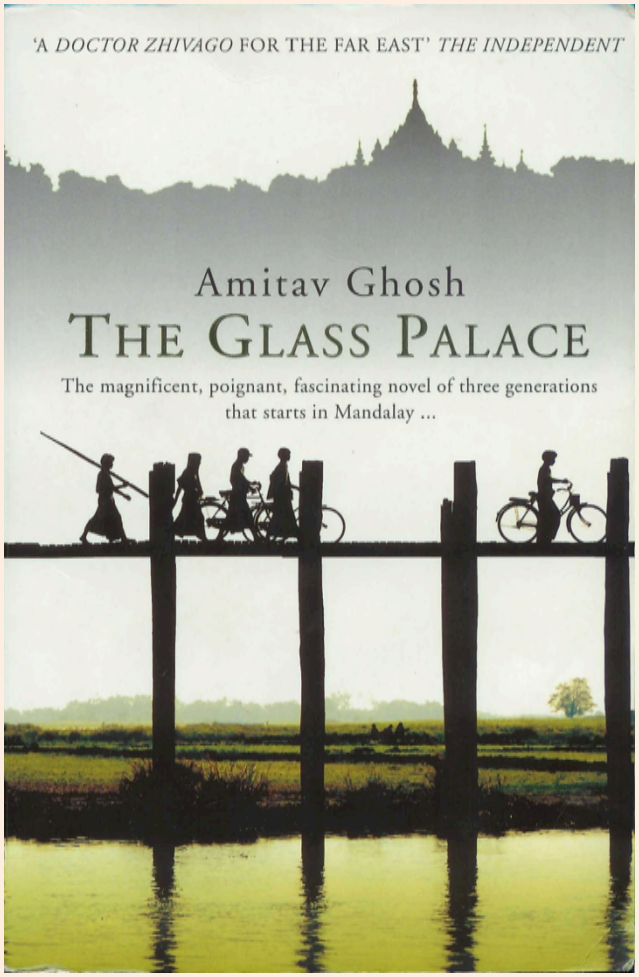
Ranking Web Pages

- 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.

Resource Description Framework (RDF)

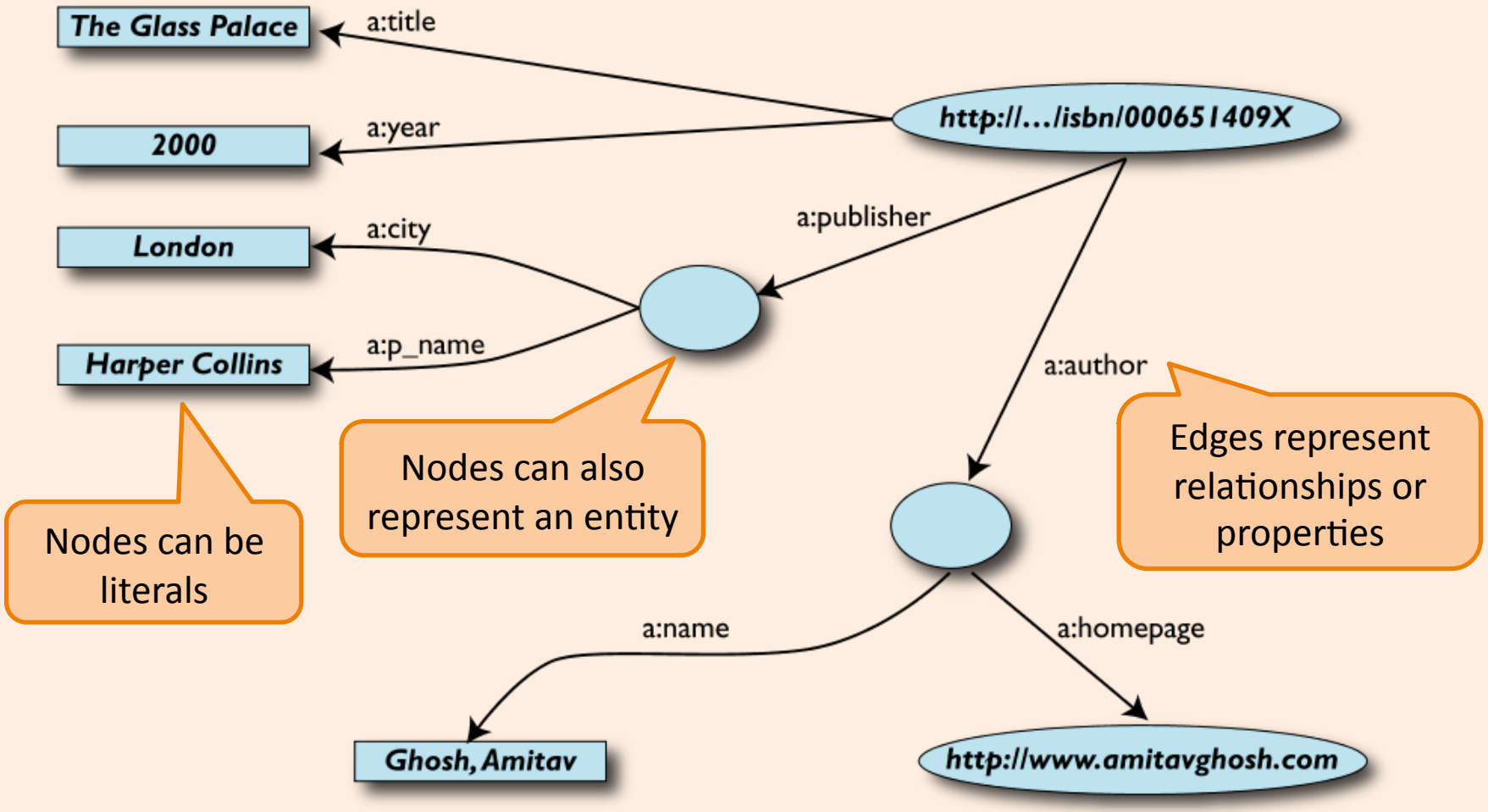


ID	Author	Title	Publisher	Year
Isbn0-00-651409-X	Id_xyz	The glass palace	Id_qpr	2000

ID	Name	Homepage
Id_xyz	Ghosh, Amitav	http://www.amitavghosh.com

ID	Publisher Name	City
Id_qpr	Ghosh, Amitav	London

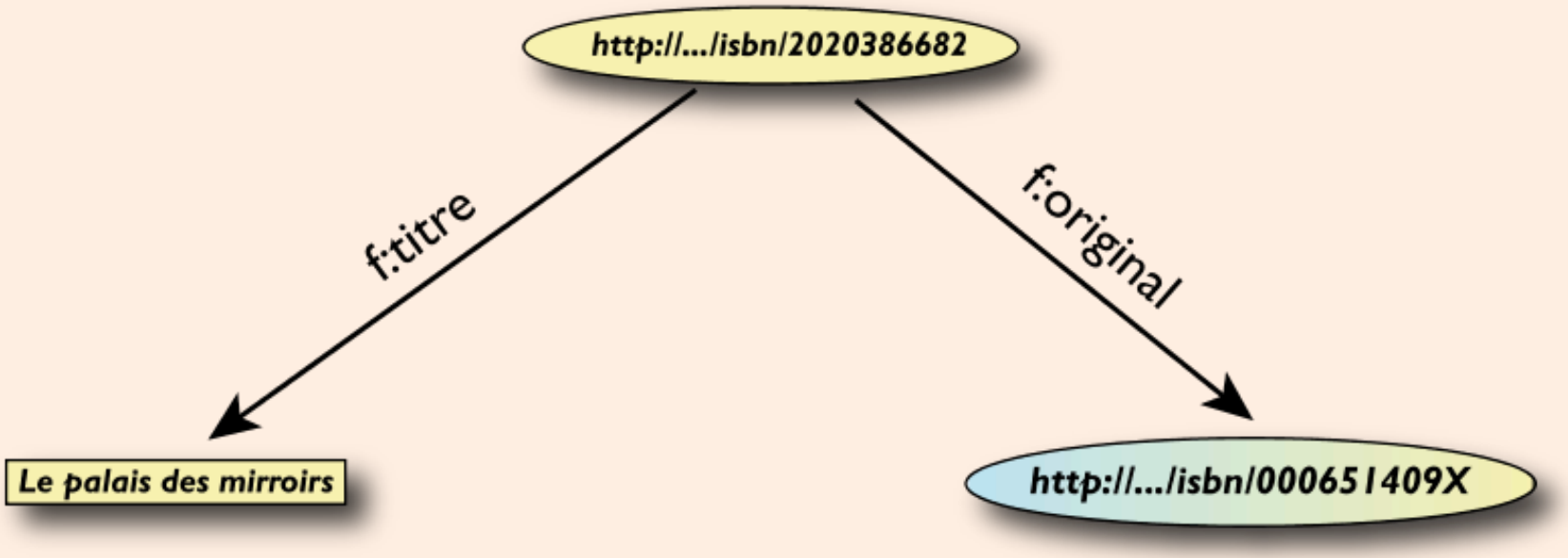
RDF Graph Data Model



More formally

- An RDF graph consists of a set of RDF triples
- An RDF triple (s,p,o)
  - "s", "p" are URI-s, ie, resources on the Web;
  - "o" is a URI or a literal
  - "s", "p", and "o" stand for "subject", "property" (aka "predicate"), and "object"
  - here is the complete triple: (<http://...isbn...6682>, <http://..//original>, <http://...isbn...409X>)
- RDF is a general model for such triples
- RDF can be serialized to machine readable formats:
  - RDF/XML, Turtle, N3 etc

RDF/XML



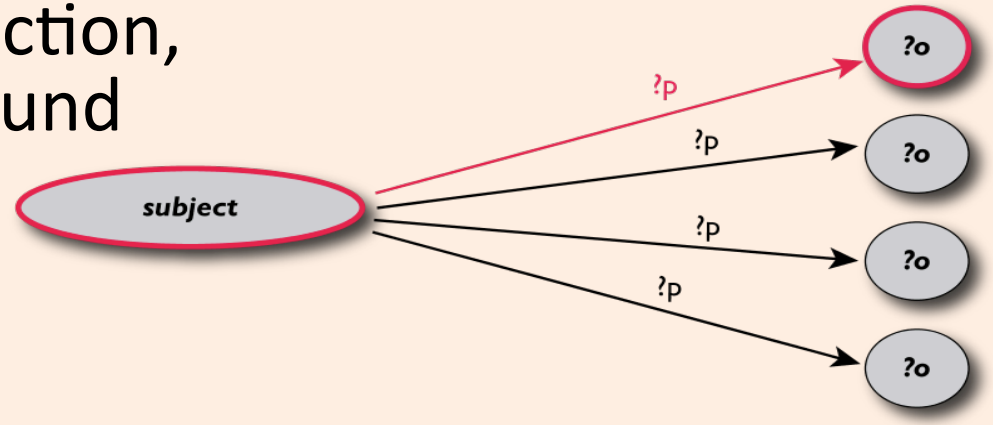

```
<rdf:Description rdf:about="http://…/isbn/2020386682">
    <f:titre xml:lang="fr">Le palais des mirroirs</f:titre>
    <f:original rdf:resource="http://…/isbn/000651409X"/>
</rdf:Description>
```

Querying RDF using SPARQL

- The fundamental idea: use graph patterns
- the pattern contains unbound symbols
- by binding the symbols, subgraphs of the RDF graph are selected
- if there is such a selection, the query returns bound resources

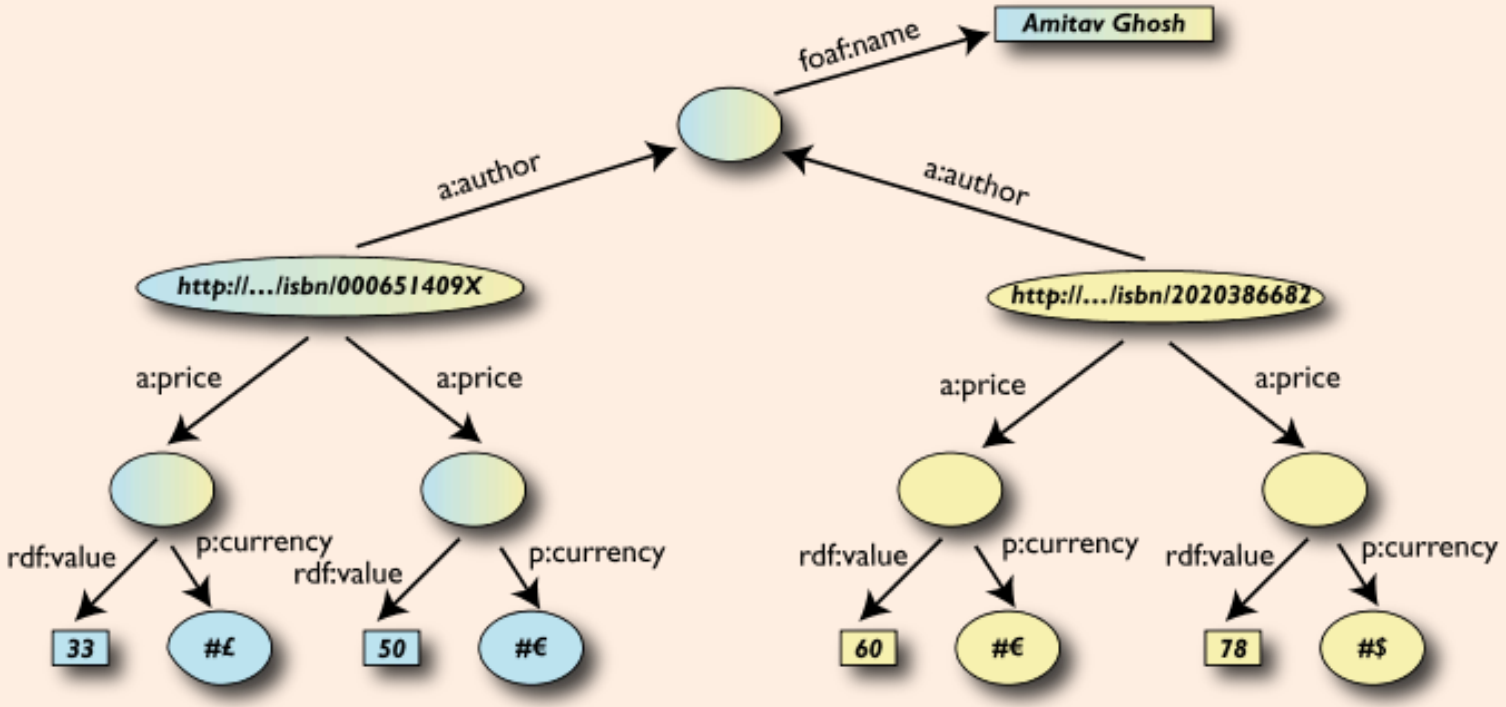
SELECT ?p ?o
WHERE {subject ?p ?o}

Where-clause defines graph patterns. ?p and ?o denote "unbound" symbols



Example: SPARQL

```
SELECT ?isbn ?price ?currency   # note: not ?x!
WHERE {?isbn a:price ?x.
       ?x rdf:value ?price.
       ?x p:currency ?currency.}
```



Linking Open Data

- Goal: “expose” open datasets in RDF
  - Set RDF links among the data items from different datasets
  - Set up, if possible, query endpoints
- Example: DBpedia is a community effort to
  - extract structured (“infobox”) information from Wikipedia
  - provide a query endpoint to the dataset
  - interlink the DBpedia dataset with other datasets on the Web

DBPedia

```
@prefix dbpedia <http://dbpedia.org/
resource/>.
@prefix dbterm  <http://dbpedia.org/
property/>.

dbpedia:Amsterdam
  dbterm:officialName "Amsterdam" ;
  dbterm:longd "4″ ;
  dbterm:longm "53" ;
  dbterm:longs "32″ ;
  dbterm:leaderName dbpedia:Job_Cohen ;
  ...
  dbterm:areaTotalKm "219" ;
  ...
dbpedia:ABN_AMRO
  dbterm:location dbpedia:Amsterdam ;
  ...
```

Amsterdam

The Keizersgracht at dusk

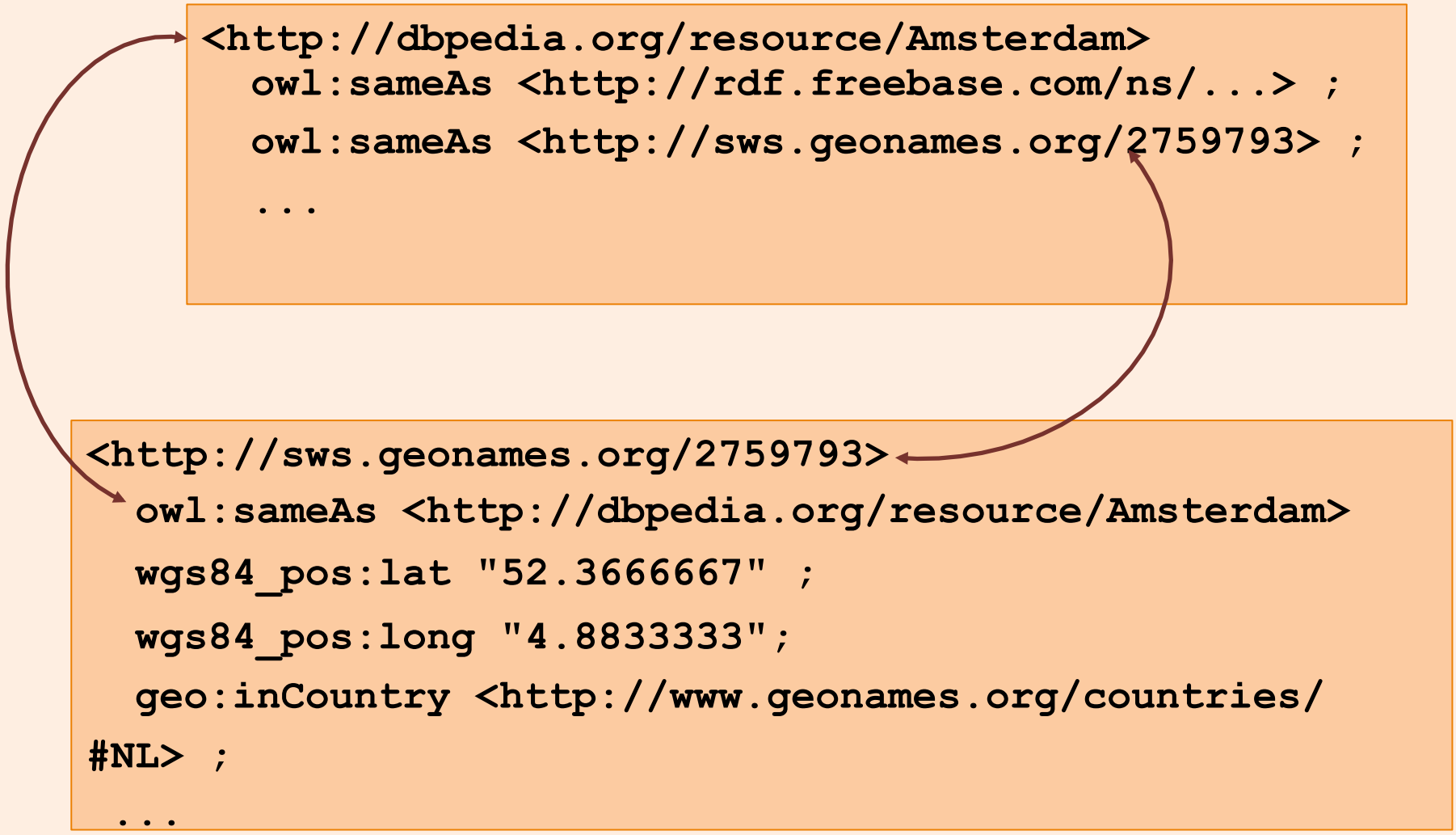
Location of Amsterdam

Coordinates: 52°22′23″N 4°53′32″E

Country	**Netherlands**
Province	**North Holland**
Government	
- Type	Municipality
- Mayor	Job Cohen[1] (PvdA)
- Aldermen	Lodewijk Asscher Carolien Gehrels Tjeerd Herrema Maarten van Poelgeest Marijke Vos
- Secretary	Erik Gerritsen
Area [2][3]	
- City	219 km² (84.6 sq mi)
- Land	166 km² (64.1 sq mi)
- Water	53 km² (20.5 sq mi)
- Urban	1,003 km² (387.3 sq mi)
- Metro	1,815 km² (700.8 sq mi)
Elevation [4]	2 m (7 ft)
Population (1 October 2008)[5][6]	
- City	755,269
- Density	4,459/km² (11,548.8/sq mi)
- Urban	1,364,422
- Metro	2,158,372
- Demonym	Amsterdammer
Time zone	CET (UTC+1)
- Summer (DST)	CEST (UTC+2)
Postcodes	1011 – 1109
Area code(s)	020

Website: www.amsterdam.nl

Linking the Data

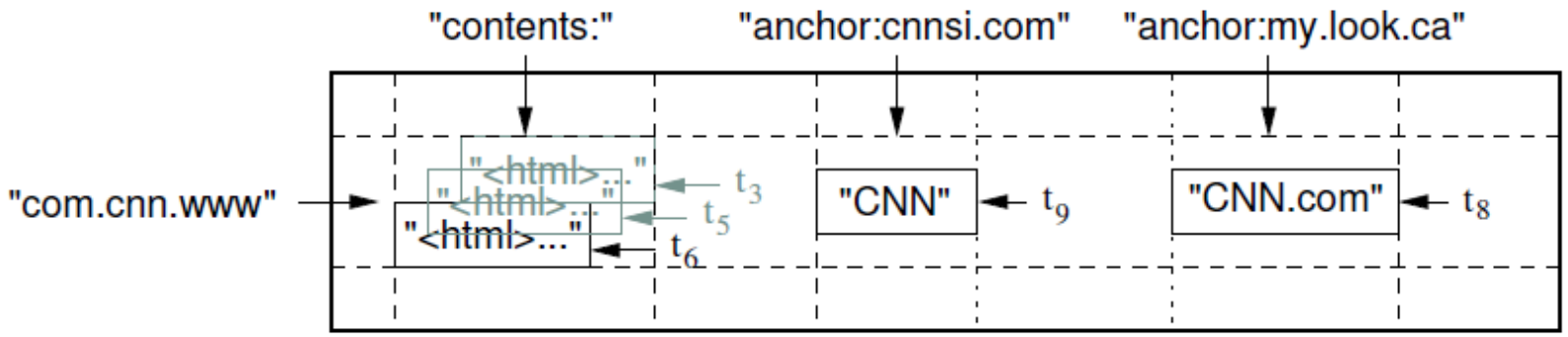


Google's Bigtable

"*Bigtable is a sparse, distributed, persistent multidimensional sorted map*"

- It is a type key-value store:
  - Key: (row key, column key, timestamp)
  - Value: uninterpreted array of bytes
- Read & write for data associated with a row key is atomic
- Data ordered by row key and range partition into "tablets"
- Column keys are organized into column families:
  - A column key then is specified using <family:qualifier>
- Timestamp is a 64 bit integer timestamp in microseconds

Example: Webpages using Bigtable



- Row key = reversed string of a webpage's URL
- Column keys:
  - contents:
  - anchor:cnnsi.com
  - anchor:my.look.ca
- Timestamps: t3, t5, t6, t8, t9

CouchDB

- A distributed document database server
  - Accessible via a RESTful JSON API.
  - Ad-hoc and schema-free
  - robust, incremental replication
  - Query-able and index-able
- A couchDB document is a set of key-value pairs
  - Each document has a unique ID
  - Keys: strings
  - Values: strings, numbers, dates, or even ordered lists and associative maps

Example: couchDB Document

```
"Subject": "I like Plankton"
"Author": "Rusty"
"PostedDate": "5/23/2006"
"Tags": ["plankton", "baseball", "decisions"]
"Body": "I decided today that I don't like baseball. I like plankton."
```

- CouchDB enables views to be defined on the documents.
  - Views retain the same document schema
  - Views can be materialized or computed on the fly
  - Views need to be programmed in javascript

Cassandra

- Another distributed, fault tolerant, persistent key-value store
- Hierarchical key-value pairs (like hash/maps in perl/python)
  - Basic unit of data stored in a "column":
    (Name, Value, Timestamp)
- A column family is a map of columns: a set of name:column pairs. "Super" column families allow nesting of column families
- A row key is associated with a set of column families and is the unit of atomicity (like bigtable).
- No explicit indexing support – need to think about sort order carefully!

Example: Cassandra