Information Retrieval

WS 2016 / 2017

Lecture 13, Tuesday January 31st, 2017
(Knowledge Bases, SPARQL, Translation to SQL)

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Overview of this lecture

- Organizational
  - Your experiences with ES12 — linear classification proof
- Content
  - Knowledge bases + SPARQL — explanation + examples
  - Databases + SQL — explanation + examples
  - SQLite — a lightweight database
  - SPARQL to SQL — algorithm + example
  - Performance — joins and join order
  - **ES13:** Implement SPARQL → SQL translation and use to process SPARQL queries with Python+SQLite

Experiences with ES12 1/3

- Summary / excerpts
  - Most of you found the exercise sheet quite easy

    "This was the shortest ex. sheet anyone ever gave to me"
  - In particular, the hint provided was quite extensive
  - Some of you doubted whether you understood it correctly, because it went so relatively easily

    "It was so easy that we felt unchallenged and didn't solve it"
  - For some it was still tricky because they don't like proofs

    "I'm not that good in proving things in a formal way"
  - Almost everybody participated in the evaluation!

Experiences with ES12 2/3

- Electromagnetic waves, wavelengths and characteristics

– γ-rays	< 10pm	decay of atomic nuclei
– X-rays	10pm .. 10nm	braking radiation fr. electrons
– Ultraviolet	10nm .. 400nm	5% of sunlight (energy-wise)
– Visible	400nm..700nm	45% of sunlight
– Infrared	700nm .. 1mm	thermal radiation, 50% of sun
– Microwave	1mm .. 1m	line-of-sight, narrow beams
– Radio waves	1m .. 100km	broadcasting, ground waves

  - Atmosphere absorbs γ- and X-rays, and most of UV and infrared

    Main absorbers: **water vapor**, carbon dioxide, ozone

    Note: lower wavelength → higher frequency → more energy

Experiences with ES12 3/3

- Electromagnetic waves
  - So, in a nutshell, our "visible range" is more or less that part of the sunlight, which is not filtered by the atmosphere
  - Understand that what we "see" is actually just "reflection data" (of electromagnetic waves from the 400nm..700nm range)

    It is as weird, as if we could see WiFi → question on ES13
  - Some animals can also see (low wavelength) infrared

    For example, they can then also "see" temperature directly

    However, water is a strong absorber of (low wavelength) infrared, so you can't use a biological organ like the eye

Knowledge Bases and SPARQL 1/7

- What is a knowledge base
  - A knowledge base is a database of statements about entities and their relations

    Critical: **unique** identifiers for each entity and relation

  - A common format / schema is to express all statements as subject predicate object triples:

Brad Pitt	acted in	Mr. and Mrs. Smith
Brad Pitt	acted in	Burn After Reading
Angelina Jolie	acted in	Mr. and Mrs. Smith
Joel Cohen	directed	Burn After Reading
Ethan Cohen	directed	Burn After Reading
Brad Pitt	married to	Angelina Jolie

Knowledge Bases and SPARQL 2/7

- Freebase and WikiData
  - Freebase is the largest open general-purpose KB to date

    Started by Metaweb in 2007, acquired by Google in 2010

    Current size: **≈3 billion** triples on **≈60 million** entities

    Freebase has become read-only in March 2015 and most of its data will eventually be merged into WikiData
  - WikiData is the soon-to-become largest open general-purpose knowledge base to data

    WikiData is the "Wikipedia" among the knowledge bases

    Current size: **≈135 million** triples on **≈25 million** entities

Knowledge Bases and SPARQL 3/7

- Reification
  - Restriction to triples is no real restriction: n-ary relationships can also be represented as triples:

m/0jy6xg	film	Finding Nemo
m/0jy6xg	actor	Ellen DeGeneres
m/0jy6xg	character	Dory
m/0jy6xg	type	Voice

m/0jy6xg is an entity name from Freebase

In the example above, it's a so-called mediator, which serves as a link between the entities it connects

The dataset for ES13 has no mediators

Knowledge Bases and SPARQL 4/7

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- Relation to the "Semantic Web"
  - The Semantic Web initiative is concerned with making knowledge base data **explicitly** available on the web

    Variant 1: semantic mark-up in normal web pages

    Typical format: Microdata or JSON-LD

    Variant 2: web pages containing only structured data

    Typical format: RDF
  - No rules that enforce consistent entity or relation names

    The hope is that people adhere to standards nevertheless, and that machines can resolve the remaining heterogeneity

    Anyway: this is **not** the topic of this lecture / course

Knowledge Bases and SPARQL 5/7

- What is SPARQL
  - The standard query language for knowledge bases

    SPARQL = **S**PARQL **P**rotocol **A**nd **R**DF **Q**uery **L**anguage
  - Example query in natural language: actors who are married and played together in at least one movie
  - The same query expressed in (simplified) SPARQL

```
SELECT ?person1 ?person2 ?film WHERE {
  ?person1  acted_in  ?film  .
  ?person2  acted_in  ?film  .
  ?person1  married_to  ?person2
}
```

Knowledge Bases and SPARQL 6/7

- SPARQL syntax
  - In the lecture today, we use a simplified syntax

    In "real" SPARQL, names of subjects / predicates / objects may contain whitespace and are surrounded by <…>
  - The actual SPARQL syntax is slightly more complicated and has many more features

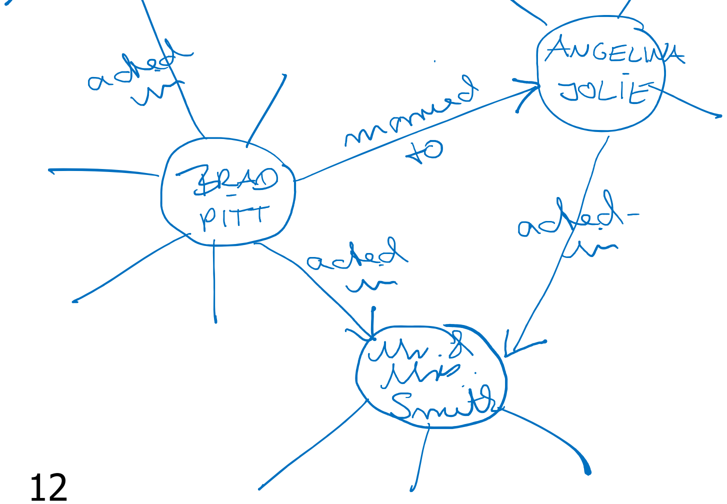
    In particular, it involves namespace prefixes, so that names can be made globally unambiguous

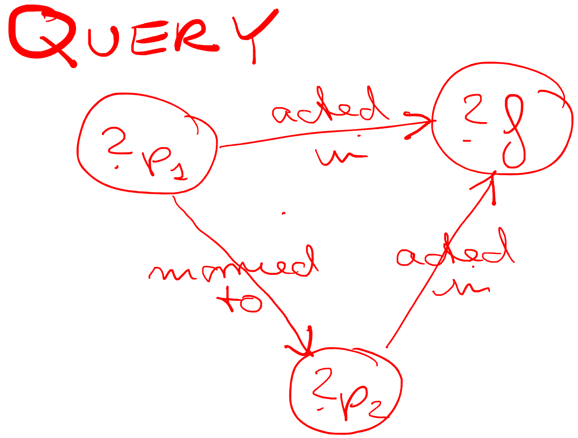
    See the Wikipedia page or the W3C specification if you are interested

    Not relevant for our lecture today

Knowledge Bases and SPARQL 7/7

- SPARQL queries as subgraphs
  - One can view a knowledge base as a **graph**, where the nodes are the entities, and the edges are the relations
  - A SPARQL query is then a sub-graph with variables at some or all of the nodes
  - Solving the query then amounts to finding all matches of the subgraph in the (large) knowledge base graph





Databases and SQL 1/4

- Introduction
  - Data from a knowledge base can also be stored in an ordinary database

    This is also what we do in the lecture and for ES13
  - The standard query language for databases is SQL

    SQL = **S**tructured **Q**uery **L**anguage
  - On the following slides, let us recap the basics from databases and SQL via a few examples

Databases and SQL 2/4

- What is a database
  - For this lecture, a database is a collection of tables, where each table has a fixed number of columns
  - For example, we could have one table for each predicate from our knowledge base, with two columns each

Table for "acted in" predicate

actor	**film**
Brad Pitt	Burn after Reading
Angelina Jolie	Mr. and Mrs. Smith
…	…

Table for "married to" predicate

person1	**person2**
Brad Pitt	Angelina Jolie
Ellen DeGeneres	Portia de Rossi
…	…

For ES13, you should work with one table (for the whole database) with three columns (subject, predicate, object)

Databases and SQL 3/4

- SQL example 1
  - Example query FROM **one** table

```
SELECT  actor
FROM    acted_in
WHERE   film = "Burn After Reading";
```

In words: all actors from movie "Burn After Reading"

Principle: select those rows from the specified table which satisfy properties specified in WHERE clause

Databases and SQL 4/4

- SQL example 2
  - Example query FROM **multiple** tables

```
SELECT   married_to.person1, married_to.person2
FROM     married_to, acted_in AS acted1, acted_in AS acted2
WHERE    married_to.person1 = acted1.actor
AND      married_to.person2 = acted2.actor
AND      acted1.film = acted2.film;
```

    In words: all couples which acted in the same movie

  - Principle: selects items from cross-product $T_1 \times \cdots \times T_k$ which satisfy properties specified in WHERE clause
  - Syntax: us AS for unique names of copies of same table; use table.column to refer to that column from that table

SQLite 1/4

- A full-fledged database, easy to install and use
  - On Debian/Ubuntu install with: sudo apt-get install sqlite3
  - Two types of commands … examples on next slides

    SQL commands: must end with a semicolon

    SQLite commands: start with a dot, no semicolon at end
  - Two modes to start SQLite:

    sqlite3 will work on an in-memory database

    sqlite3 <name>.db create database in that file, and if file exists, use database from that file

    Let's read our example tables in SQLite using the commands from the next two slides … it's easy

SQLite 2/4

- Some useful SQLite commands by example
  - Specifies the column separator used for input and output

    .separator "	" use Ctrl+V TAB for TAB !
  - Read table from TSV (tab-separated values) file

    .import film.tsv film
  - Execute commands from script file (typical suffix is .sql)

    .read <file with commands>
  - Show execution time of every command

    .timer on

SQLite 3/4

- Some useful SQL commands by example
  - Create a table with a given schema

    CREATE TABLE acted_in(actor TEXT, film TEXT);
  - Create an index for a column of a table

    CREATE INDEX acted_in_index ON acted_in(actor);
  - Extract / combine data from tables

    SELECT * FROM acted_in WHERE … LIMIT 100;
  - Delete table / index (without error msg if it's not there)

    DROP TABLE IF EXISTS acted_in;

    DROP INDEX IF EXISTS acted_in_index;

SQLite 4/4

- Python interface to SQLite
  - Executing SQL commands to a SQLite database from within Python is very easy:

```
import sqlite3
db = sqlite3.connect("example.db")
cursor = db.cursor()
cursor.execute("SELECT * FROM table")
for row in cursor.fetchall():
    print("\t".join(row))
```

Beware: the SQLite commands (starting with a dot) cannot be executed from within Python, you need SQLite for those

SPARQL to SQL Translation 1/4

- Motivation
  - We want to translate a given SPARQL query to a SQL query that gives the desired results on a given database
  - In the following example, we use one table per relation

    CREATE TABLE acted_in(actor TEXT, film TEXT)
    CREATE TABLE married_to(person1 TEXT, person2 TEXT)

    Note: all elements from one table are from one relation, so we don't need to store the relation name in the table

    For ES13, use **one big table** for all the data, with three columns named **subject**, **predicate**, **object**

    This is deliberately different from how we did it in the lecture, so that you have to do some thinking yourself

SPARQL to SQL Translation 2/4

- Example
  - SPARQL query

```
SELECT ?p1 ?p2 ?f WHERE {
   ?p1  acted_in  ?f .
   ?p2  acted_in  ?f .
   ?p1  married_to  ?p2          }
```

  - SQL query:

```
SELECT  married_to.person1, married_to.person2, acted1.film
FROM    married_to, acted_in AS acted1, acted_in AS acted2
WHERE   married_to.person1 = acted1.actor
AND     married_to.person2 = acted2.actor
AND     acted1.film = acted2.film;
```

SPARQL to SQL Translation 3/4

- Algorithm
  - It is up to you in ES13, to design a generic algorithm that works for arbitrary basic SPARQL queries

    Of the form SELECT <vars> { <triples> }
  - The algorithm is not difficult, but requires understanding of how the data is stored and how SPARQL and SQL work

    So perfect exercise to understand the basics !
  - On the next slide we give you some valuable advice

SPARQL to SQL Translation 4/4

- Algorithm, advice for ES13
  - If there are k query triples in the SPARQL query, have k entries in the FROM clause of the SQL query

    FROM freebase as f1, freebase as f2, ... , freebase as fk

  - In your code, for each variable from the SPARQL query, build an **array** of all its occurrences in the query, e.g.

    ?x: f1.subject, f2.object, f5.object

  - Then, when building the SQL query, add the corresponding equalities to the WHERE clause, e.g.

    WHERE f1.subject = f2.object AND f2.object = f5.object

    Note: if ?x occurs m times, m – 1 equalities are enough

Performance 1/4

- Cross product of tables
  - Recall that, conceptually, an SQL statement like

    SELECT … FROM $T_1, T_2, \ldots, T_k$ WHERE …

    selects elements from the **cross-product**

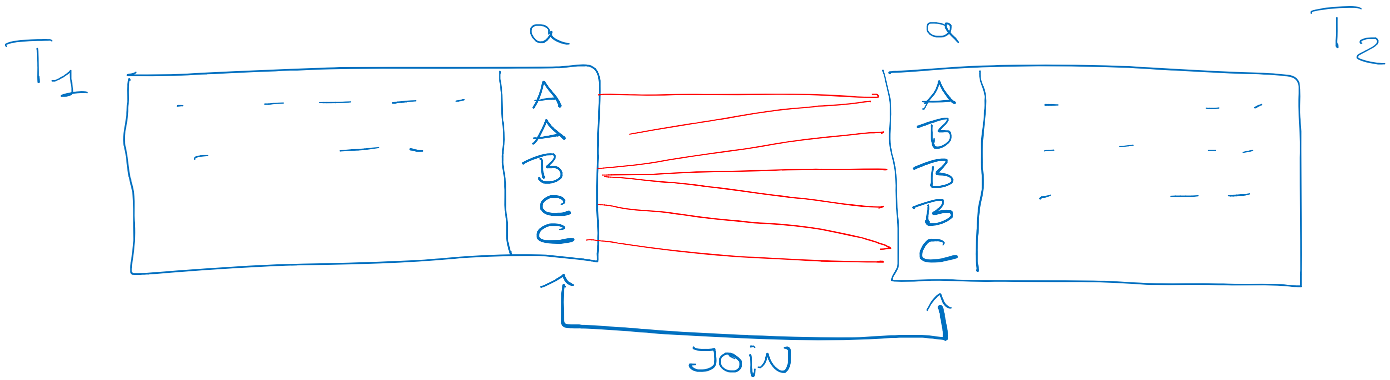
    $T_1 \times \cdots \times T_k$ (which has $|T_1| \cdot \cdots \cdot |T_k|$ elements)

    (where some or all of the T_i can be the same table)

Performance 2/4

- Joining of tables
  - Each … = … in the WHERE clause effectively ask for a JOIN operation between two tables
  - Algorithmically, a JOIN requires a **list intersection**
  - If we CREATE an index for the respective tables on the respective join attributes, this list intersection gets fast

    E.g., by sorting (a copy of) the table by that attribute



Performance 3/4

- Join ordering
  - Typical SQL-from-SPARQL queries require multiple joins
  - Order of joins can make a **huge** performance difference
  - For our example query, the acted_in table (actors – films) is more than ten times larger than the married_to table
  - Join order 1: look at all pairs of actors who played in the same film, and for each check whether they are married

    materialized all pairs of actors from same film (large)
  - Join order 2: look at all married couples and for each get their films and check whether they overlap

    materializes list of films of all married people (small)

Performance 4/4

- Join ordering, continued
  - Without further ado, SQLite seems to take the order of the tables in the FROM clause as its join order

```
SELECT  married_to.person1, married_to.person2
FROM    acted_in as acted1, acted_in as acted2, married_to
WHERE   married_to.person1 = film1.actor
AND     married_to.person2 = film2.actor
AND     acted1.film = acted2.film;
```

Alternatives: (note that there are 6 possible orderings)

```
FROM    married_to, acted_in as acted1, acted_in as acted2
```

```
FROM    married_to, acted_in as acted2, acted_in as acted1
```

References

- Textbook
  - Nothing about this topic in the text book by Manning, Raghavan, and Schütze
- Wikipedia
  - http://en.wikipedia.org/wiki/Knowledge_base
  - http://en.wikipedia.org/wiki/SPARQL
  - http://en.wikipedia.org/wiki/SQL
  - http://en.wikipedia.org/wiki/SQLite
  - http://en.wikipedia.org/wiki/Freebase