Dealing with the Deep Web and all its Quirks

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31 August 2012, *VLDS*

The Deep Web

Definition (Deep Web, Hidden Web, Invisible Web)

All the content on the Web that is not directly accessible through hyperlinks. In particular: HTML forms, Web services.

Size estimate: 500 times more content than on the surface Web! [BrightPlanet, 2001]. Hundreds of thousands of deep Web databases [Chang et al., 2004]

Sources of the Deep Web

Example

- *Yellow Pages* and other directories;
- Library catalogs;
- Weather services;
- Real-estate agencies;
- etc.

. . . but also lots of information available on the surface Web, but that may be interesting to retrieve from the deep Web:

- more structured
- easier to retrieve the information of interest
- less network accesses to crawl the whole database

A Quirky Deep Web

- Numerous works on form understanding and information extraction from the deep Web [He et al., 2007, Varde et al., 2009, Khare et al., 2010]
- Formal models for answering queries under access pattern restrictions [Li and Chang, 2001, Calì and Martinenghi, 2008, Calì and Martinenghi, 2010, Benedikt et al., 2012a]
- Siphoning of hidden Web databases [Barbosa and Freire, 2004, Jin et al., 2011, Sheng et al., 2012]

- Those works ignore lots of quirky dimensions of deep Web interfaces
- Here: towards a more comprehensive framework for deep Web modeling and querying

Outline

Views

Deep Web sources offer views over (most often relational) data, through, at the very least:

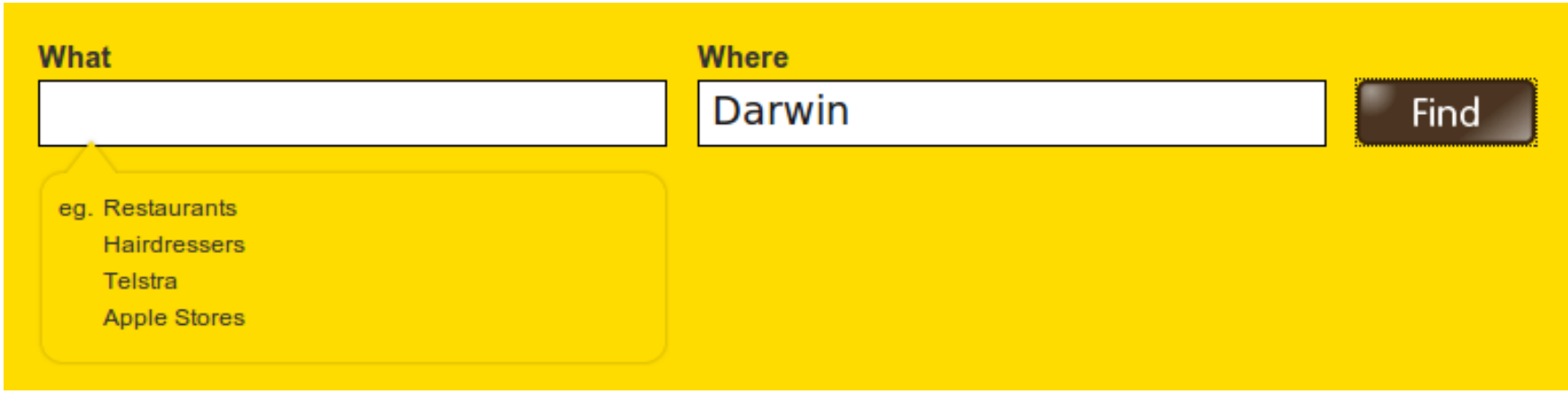
- selection (depending on user's query, or implicit in the service), in particular inequalities
- projection (not available attributes are exported by a given service)

And also (but less critically):

- joins (quite common in a Web application – but from an outsider's perspective, often enough to see the result of a join as the relation of interest)
- union, intersection, difference, etc. (relatively rare)
- aggregation (usually not the most important part of the service)
- more complex processing (rare in practice)

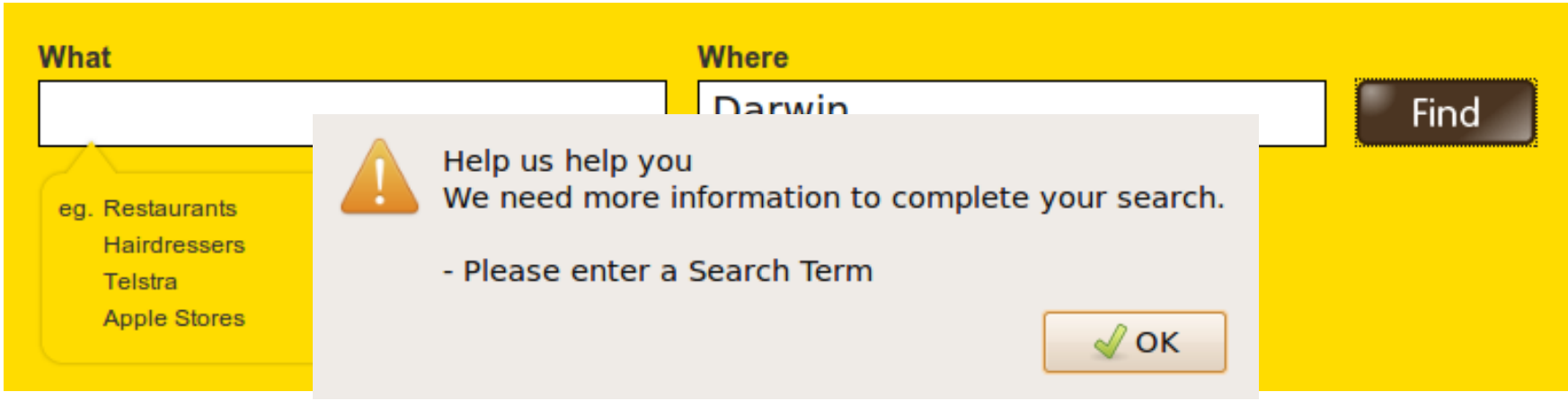
Limited access patterns

Australian Yellow Pages search form:



Limited access patterns

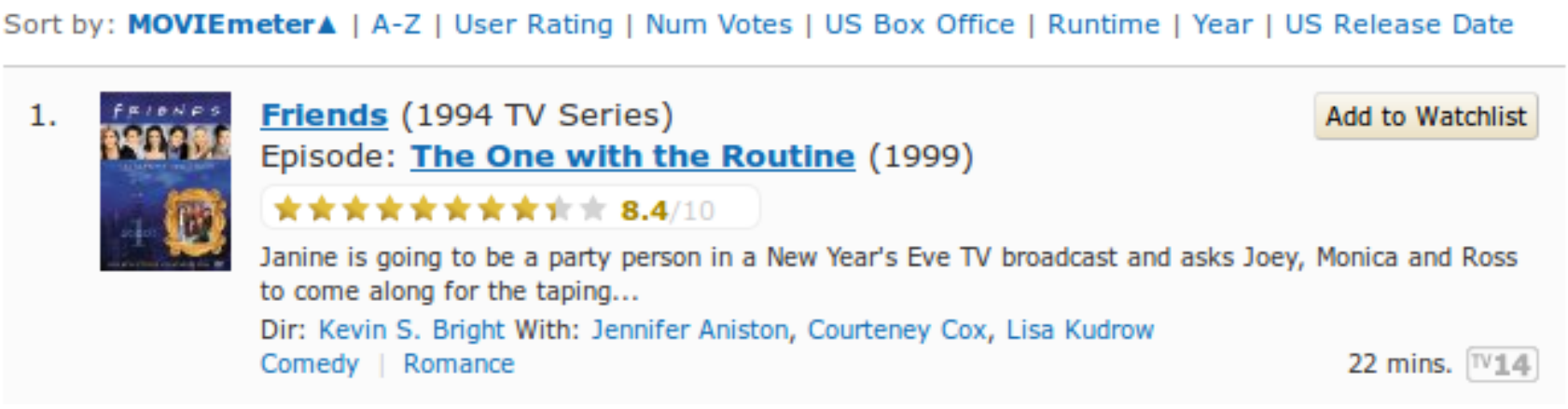
Australian Yellow Pages search form:



Required attributes, dependencies between attributes of the form, etc.

Ranking of results

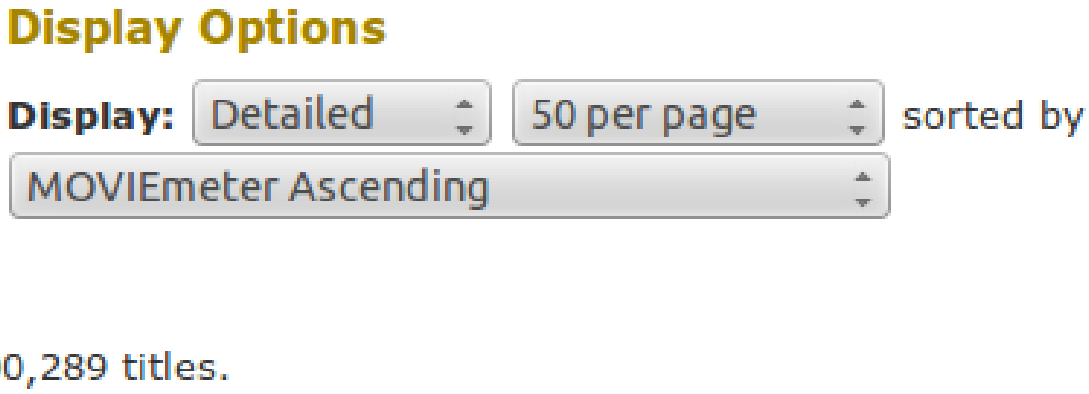
IMDb advanced search sort criteria:



Different possible sort criteria, some according to non-exported attributes

Paging

Paging in IMDb:



Each page of results requires a separate network access, and therefore has a cost

Overflow

What you get when you try to access the 100,001-th result to an IMDb advanced query:

Error

Sorry, IMDb does not serve more than 100000 results for any query. (You asked for results starting from 100001)

Only a (top-ranked) subset of the results is available for each access

Policy limitations

Twitter API rate limitation:

REST API Rate Limiting

The default rate limit for calls to the REST API varies depending on the authorization method being used and whether the method itself requires authentication.

- Unauthenticated calls are permitted 150 requests per hour. Unauthenticated calls are measured against the public facing IP of the server or device making the request.
- OAuth calls are permitted 350 requests per hour and are measured against the `oauth_token` used in the request.

Limited rate of queries per minute, hour, query... Several services of the same source may share the same limits.

Incomplete information: Projection

Several views of the same information on IMDB:

It's a Wonderful Life (1946) Top 5000

UR 130 min - Drama | Fantasy - 7 January 1947 (USA)

8.7

Your rating: ★★★★★★★★★★ -/10

Ratings: **8.7**/10 from 146,420 users

Reviews: 556 user | 162 critic

An angel helps a compassionate but despairingly frustrated businessman by showing what life would have been like if he never existed.

Director: Frank Capra

Writers: Frances Goodrich (screenplay), Albert Hackett (screenplay), and 4 more credits »

Stars: James Stewart, Donna Reed and Lionel Barrymore | See full cast and crew

+ Watchlist | Share...

Incomplete information: Projection

Several views of the same information on IMDB:

1. It's a Wonderful Life (1946)
   - aka "Frank Capra's It's a Wonderful Life" - USA *(complete title)*
   - aka "La vie est belle" - Belgium *(French title)*, Canada *(French title)*, France
   - aka "¡Qué bello es vivir!" - Peru *(imdb display title)*, Spain
   - aka "Ist das Leben nicht schön?" - Austria *(TV title)*, West Germany *(TV title)*
   - aka "¡Que bello es vivir!" - Uruguay
   - aka "A Felicidade Não Se Compra" - Brazil
   - aka "Az élet csodaszép" - Hungary
   - aka "Det er herligt at leve" - Denmark
   - aka "Divan život" - Serbia
   - aka "Divan zivot" - Yugoslavia *(Croatian title)* *(imdb display title)*
   - aka "Do Céu Caiu Uma Estrela" - Portugal
   - aka "Ihmeellinen on elämä" - Finland
   - aka "La vita è meravigliosa" - Italy
   - aka "Livet är underbart" - Sweden
   - aka "Livet er vidunderlig" - Norway *(imdb display title)*
   - aka "Mens, durf te leven" - Netherlands *(informal literal title)*
   - aka "Mia yperohi zoi" - Greece *(transliterated ISO-LATIN-1 title)*
   - aka "O viata minunata" - Romania *(imdb display title)*
   - aka "Qué bello es vivir" - Argentina
   - aka "Que bonic és viure!" - Spain *(Catalan title)*
   - aka "Que la vie est belle" - Belgium *(French title)*
   - aka "Sahane hayat" - Turkey *(Turkish title)* *(DVD title)*
   - aka "Subarashiki kana, jinsei!" - Japan
   - aka "To wspaniale zycie" - Poland
   - aka "Wat een mooi leven" - Belgium *(Flemish title)*
   - aka "Zycie jest cudowne" - Poland

Incomplete information: Projection

Several views of the same information on IMDB:

1.  **It's a Wonderful Life** (1946) — Add to Watchlist
8.7/10
An angel helps a compassionate but despairingly frustrated businessman by showing what life would have been like if he never existed.
Dir: Frank Capra With: James Stewart, Donna Reed, Lionel Barrymore
Drama | Fantasy
130 mins. UR

2.  **It Happened One Night** (1934) — Add to Watchlist
8.3/10
A spoiled heiress, running away from her family, is helped by a man who's actually a reporter looking for a story.
Dir: Frank Capra With: Clark Gable, Claudette Colbert, Walter Connolly
Comedy | Romance
105 mins. UR

3.  **Mr. Smith Goes to Washington** (1939) — Add to Watchlist
8.4/10
A naive man is appointed to fill a vacancy in the US Senate. His plans promptly collide with political corruption, but he doesn't back down.
Dir: Frank Capra With: James Stewart, Jean Arthur, Claude Rains
Comedy | Drama
129 mins. Approved

Same relation(s), different attributes projected out

Incomplete information: Granularity

Release date API on IMDb:

Release dates for

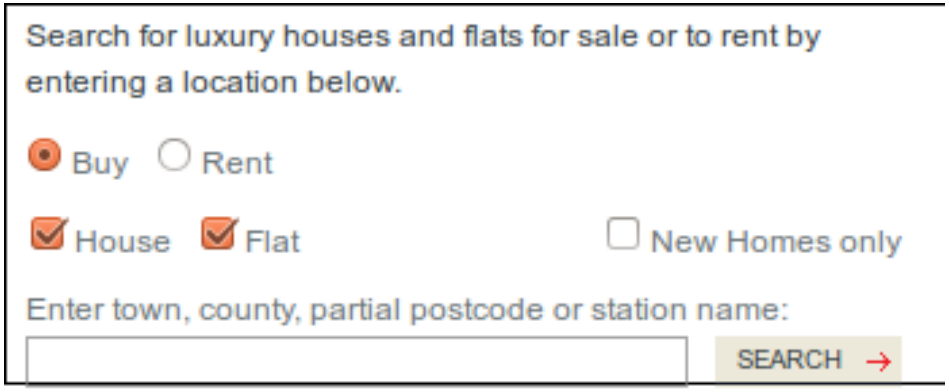
It's a Wonderful Life (1946) More at IMDbPro »

Country	Date
USA	20 December 1946 (New York City, New York)

The granularity of the presented information may not be the most precise one

Recency

Savills property search:

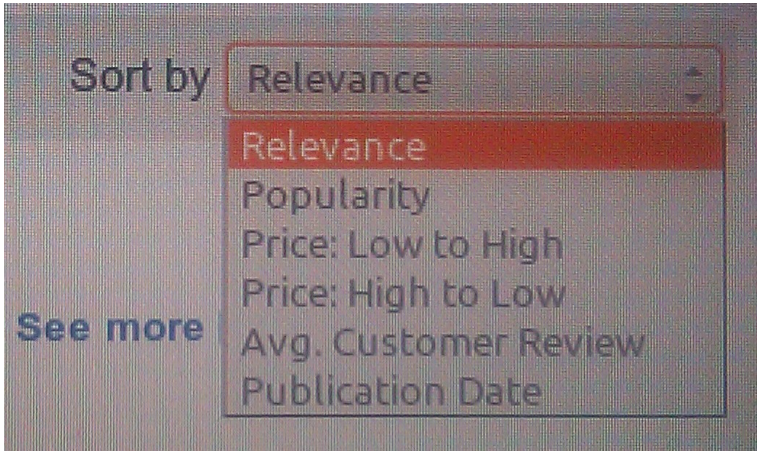


Publication time is a special attribute of interest:

- may or may not be exported
- may or may not be queriable (sometimes in a very weird way!)
- often used as a ranking criterion
- granularity plays an important role
- publication date $<$ query date

Uncertainty in the ranking

Amazon Books sorting options:



- Proprietary ranking functions
- Weighted combination of attributes with unknown weights [Soliman et al., 2011]
- Ranking according to an unexported attribute

Dependencies across services

Some of IMDb advanced search options:

Advanced Title Search

Want to get a list of comedies from the 1970s that have at least 1000 votes and an average rating of 7.5 or higher? Use Advanced Title Search.

Advanced Name Search

Want a list of males in the database who are Virgos and over 6 feet tall? Use Advanced Name Search.

Collaborations and Overlaps

Want a list of titles in which both Brad Pitt and George Clooney appeared? Or a list of people who worked on both Forrest Gump and Apollo 13? Try searching Collaborations and Overlaps.

- services of the same source provide different correlated views of the same data
- dependencies (inclusion) across services are common too
- a given service often satisfies some key dependencies

But also...

- non-conjunctive forms (common in digital library applications)
- unknown characteristics of information retrieval systems (keyword querying vs exact querying, indexing of stop words, stemming used, etc.)
- intricate interactions (AJAX autocompletion, submitting a form as a first step before submitting another form, etc.)
- potential side effects of a service

Outline

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Features of the query language

What does a user need out of a deep Web query language?

- Selection, projection, joins, union (of different sources)
- Custom ranking
- Top-k results of a query

But also:

- Proper uncertainty management
- Deduplication of query results
- Diversification of query results
- Explanation of query results

Desirable model properties

Declarative framework (specifying what a user wants, not how to retrieve it)

Composability: Web services, queries, materialized views expressible in a common language

Incremental maintenance support

Familiarity with the query language (e.g., relying on SQL when possible)

Cost model for accessing a deep Web source, paging, utilizing a materialized view, etc.

Outline

Example service: Hotel availability

```
CREATE VIEW HotelsService1($c,$o) AS
SELECT name, city, price, AvailableRooms,
       rating, DAY(LastUpdate)
FROM Hotels1
WHERE city=$c
ORDER BY rating DESC
LIMIT $o,10 UP TO 1000
```

- Parametrized view over a (hidden) source relation
- Main idea: Reproduce a (possible) SQL implementation of the view
- Showcased: selection, projection, access patterns, granularity, ranking, paging, overflow

Example service: Mapping

```
CREATE VIEW MapService($locX,$locY,$radius, $o) AS
SELECT name, HotelLocX,HotelLocY,
square(HotelLocX-$locX) + square(HotelLocY-$locY) As D
FROM GeoDB
WHERE D < square($radius)
ORDER BY SqrDist ASC
LIMIT $o,10
```

Query

```
SELECT Hotels1.name, Hotels2.name
FROM (HotelsService1+HotelsService2+MapService) As H1,
     (HoteslService1+HotelsService2+MapService) As H2
WHERE H1.city= 'Istanbul' AND H2.city='Istanbul'
AND H1.rating > 4
AND H2.rating > 4
AND square(H1.HotelLocX-H2.HotelLocX) +
    square(H1.HotelLocY-H2.HotelLocY) < 1000
```

The "+" operator combines services using any combination of accesses (in particular, union, natural join)

Outline

Problems of Interest

Algorithms for, and complexity of, the following problems:

- Given a collection of services, is a query realizable? Combines problems from answering queries using views [Halevy, 2001], limited access patterns [Calì and Martinenghi, 2010], feasability of a ranking function, taking into account overflow...
- What is the optimal plan for realizing a query?

  Static plans: requires a proper query plan (recursive) formalism, and a static cost model

  Dynamic plans: partial execution and reevaluation of the cost – what is the best access I can do at a given time [Benedikt et al., 2011]

Outline

Inference of the model from real services

How to automatically infer such a model from real-world forms?

- Heuristics to detect paging, overflow, etc.
- Combine classical form understanding and information extraction systems to understand the properties of a service: making assumptions, and then probing to confirm these assumptions [Oita et al., 2012]
- Software testing methods to test a wide range of possible combinations of attributes and infer the corresponding behavior of the interface
- Perform static analysis on client-side code to detect all such characteristics enforced on the client side [Benedikt et al., 2012b]
- Make use of the different services of the same source to holistically learn their characteristics

Summary and perspectives

- Many quirky aspects often ignored but crucial in deep Web services
- A proper query answering system requires consider them together, not in isolation
- Towards a composable, declarative, model for deep Web querying together with a cost model

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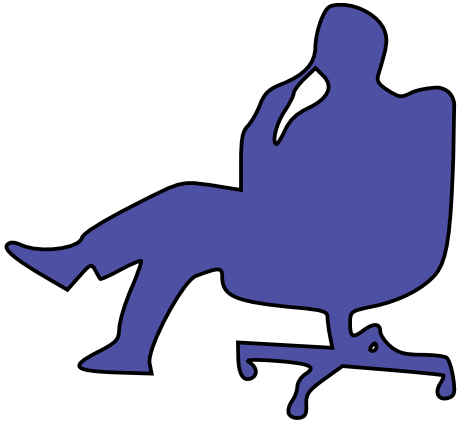

- Full design of the data and query model
- Characterization of the complexity of the considered problems
- Query planning algorithms

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