Personalized Concept-based Search & Exploration on the Web of Data using Results Categorization

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Outline

- Challenges & Motivation
- Personalized Concept-based Search
  - Walk through
  - Categorisation & Personalisation
- Evaluations
- Conclusions and Future Work

Web of Data (WoD)

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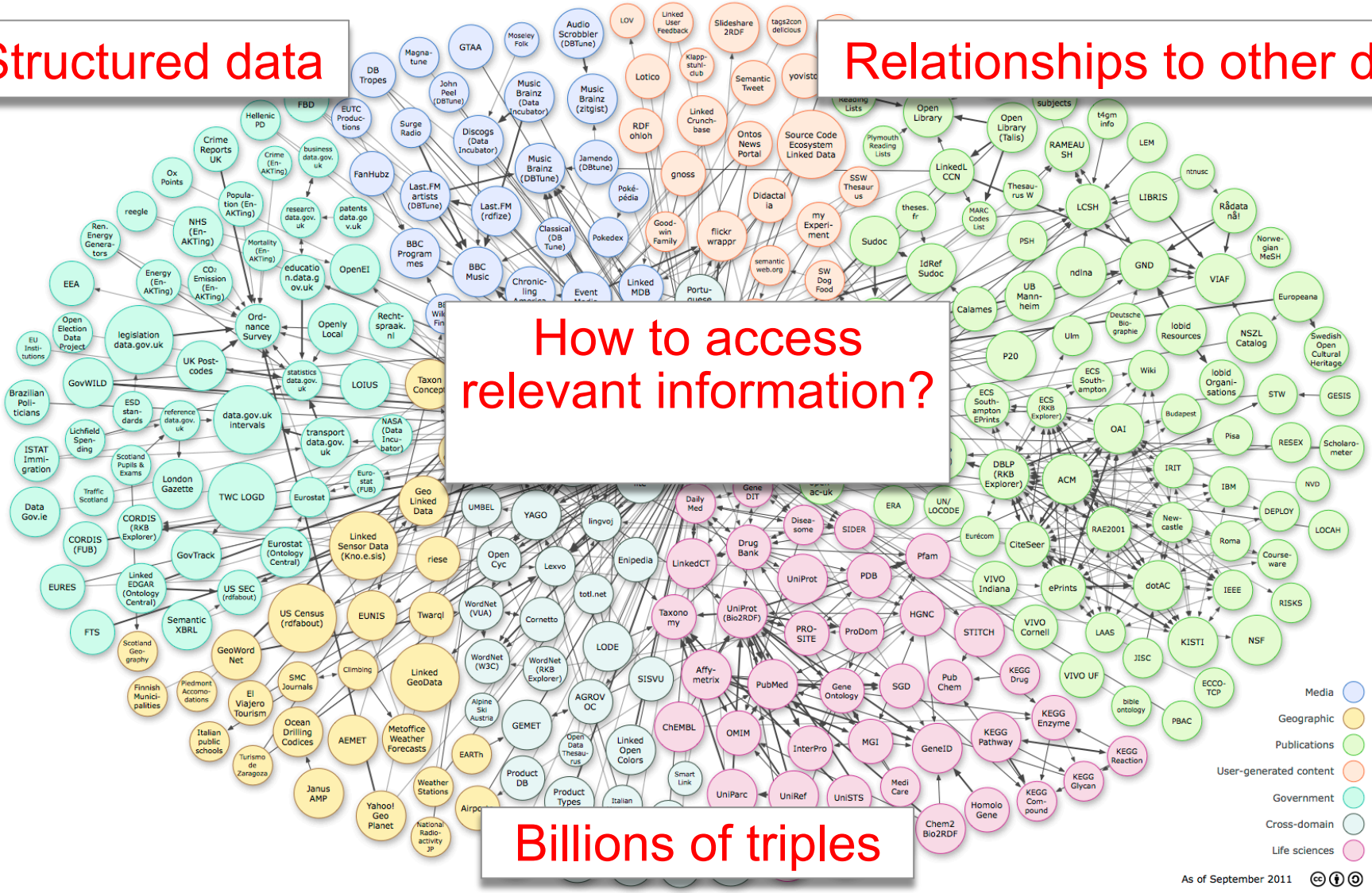
Structured data

Relationships to other data

How to access relevant information?

Billions of triples



Challenges for Search over WoD

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- Increasing challenge of finding and exploring relevant information on ever expanding WOD
- Support information queries & data gathering (~80% of Web queries)

- Today's LoD search engines present results as ranked lists (e.g. Sindice, Watson)
- Need for more 'Guided, Personalised support' for users
  - Provide more scaffolded, informed navigation
  - **Increase Result Precision**
  - Increase User Satisfaction

Challenges (cont)

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Guided or Faceted search/browse interfaces is another approach for exploratory search

- Facet generation is bound to specific datatype/object properties
- Typically applied in closed domains since it requires high data completeness and consistent markup across the whole corpus
- Can suffer Scalability & performance issues (due to dynamic conjunctive clauses)
- Difficult to generate useful facets for large and heterogeneous data

Motivation

- Results clustering and personalized search are popular methods Information Retrieval (IR)

Results clustering:

- Organize results into categories
- Useful for results exploration & disambiguation
- Some categories are widely used e.g. Google categories, Yahoo Directories, Open Directory Project

Personalized search:

- improve retrieval effectiveness by adapting results to context/interests of individual users
- Also personalized search and interactions can become more important as the size of LOD increases especially for dialogic interfacces

Proposal: Personalised Concept-based Search Mechanism for the WoD

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Objective:

… to evaluate novel personalized search and exploration strategies for WoD:

Approach

- Develop Innovative combination of results categorization and personalized IR
- Use a novel fuzzy retrieval model for automatic categorization of LOD resources into UMBEL (Sah & Wade 2012)
- Group the results related to the same concepts to form *concept lenses*, to assist end user exploratory search and browsing
- Perform runtime personalisation based on User interactions (i.e. clicks on a concept lens or a search result) to adapt the results and results' display to individual needs

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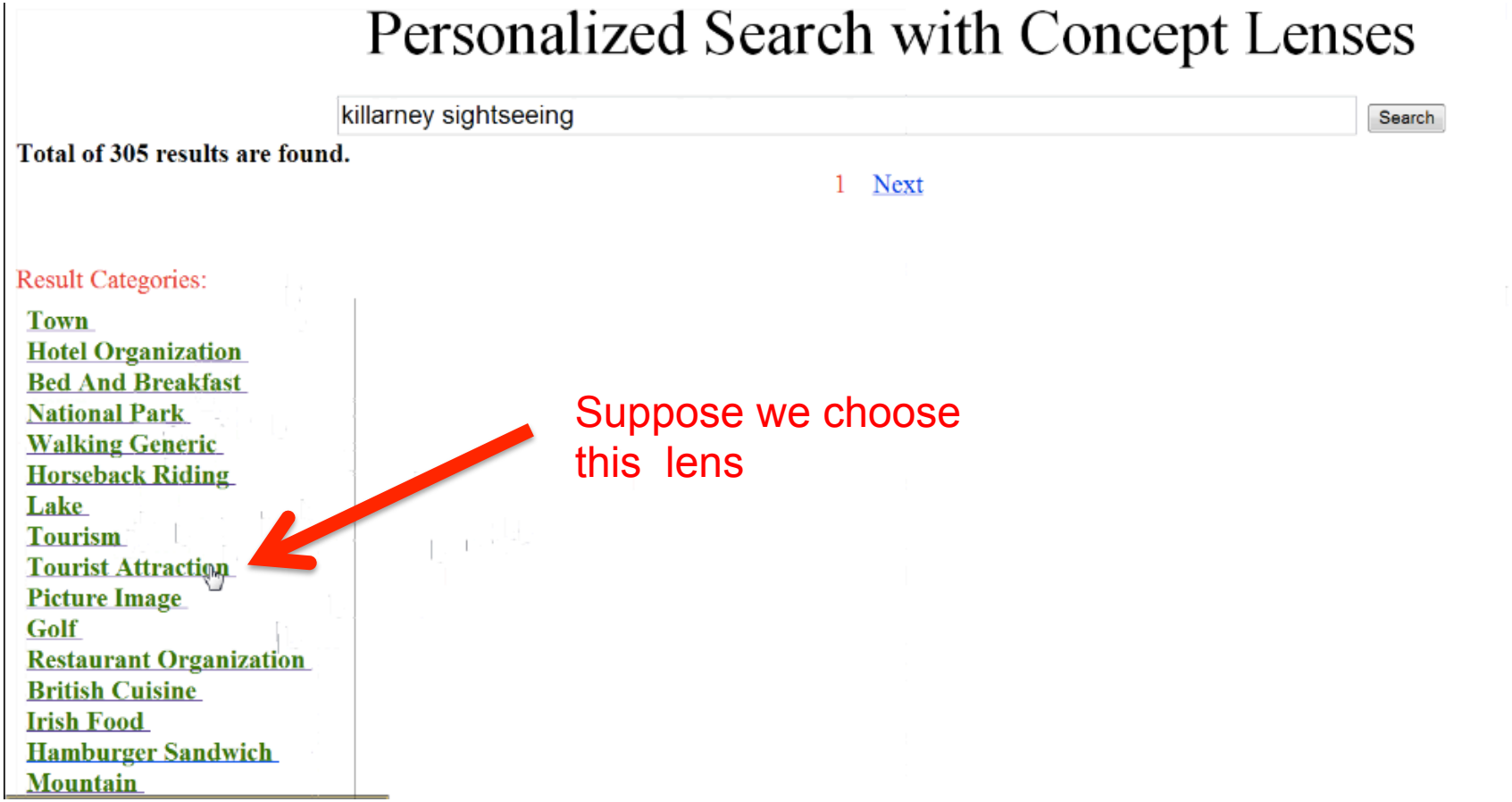
Personalized Search with Concept Lenses

killarney sightseeing Search


Personalized Search with Concept Lenses
killarney sightseeing
Search
Total of 305 results are found.
1 Next
Result Categories:
Town
Hotel Organization
Bed And Breakfast
National Park
Walking Generic
Horseback Riding
Lake
Tourism
Tourist Attraction
Picture Image
Golf
Restaurant Organization
British Cuisine
Irish Food
Hamburger Sandwich
Mountain
Suppose we choose this lens

Personalised re-ranking of Concept lenses

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Tourist Attraction
Horseback Riding
Tourism
Golf
Mountain
Walking Generic
National Park
Bar Place
Hotel Organization
Bed And Breakfast
Hamburger Sandwich
British Cuisine
Irish Food
Picture Image
Restaurant Organization
Italian Cuisine
Mexican Cuisine
Thai Cuisine
Continental Cuisine
Cafe Organization
Town
Lake

Result re-ranking and Query expansion based on selection of lens

Tourist Attraction

Things to do in Killarney – 60 Killarney Attractions - TripAdvisor
http://www.tripadvisor.ie/Attractions-g186612-Activities-Killarney_County_Kerry.html
★★★★★ 2,685 reviews and photos of 60 things to do in Killarney, Ireland....

More Results

Gap of Dunloe - Killarney - Reviews of Gap of Dunloe - TripAdvisor
http://www.tripadvisor.ie/Attraction_Review-g186612-d659775-Reviews-Gap_of_Dunloe-Killarney_County_Kerry.html
Gap of Dunloe, Killarney: See 315 reviews, articles, and 153 photos of Gap of Dunloe, ranked No.2 on TripAdvisor among 60 attractions in Killarney.sim 0.5

Meeting of the Waters - Killarney - Reviews of Meeting of the Waters - TripAdvisor
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Killarney Guided Walks - Killarney - Reviews of Killarney Guided Walks - TripAdvisor
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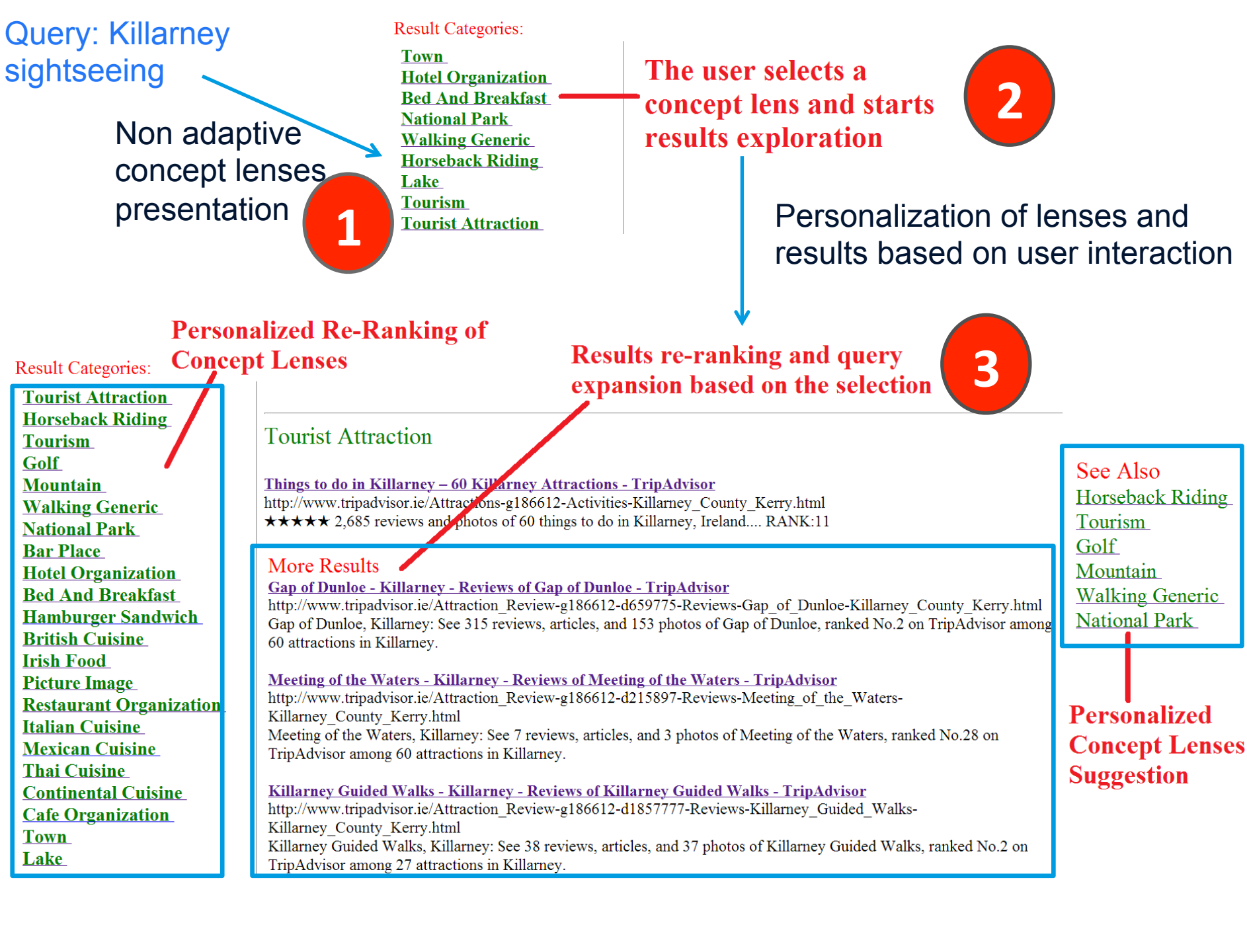
Killarney Guided Walks, Killarney: See 38 reviews, articles, and 37 photos of Killarney Guided Walks, ranked No.2 on TripAdvisor among 27 attractions in Killarney.sim 0.5

Killarney Riding Stables - Killarney - Reviews of Killarney Riding Stables - TripAdvisor
http://www.tripadvisor.ie/Attraction_Review-g186612-d3249993-Reviews-Killarney_Riding_Stables-Killarney_County_Kerry.html
Killarney Riding Stables, Killarney: See 8 reviews, articles, and 5 photos of Killarney Riding Stables, ranked No.12 on TripAdvisor among 60 attractions in Killarney.sim 0.5

See Also
Horseback Riding
Tourism
Golf
Mountain
Walking Generic
National Park

Personalised Concept Lense Suggestion


Query: Killarney sightseeing
Non adaptive concept lenses presentation
1
Result Categories:
Town
Hotel Organization
Bed And Breakfast
National Park
Walking Generic
Horseback Riding
Lake
Tourism
Tourist Attraction
The user selects a concept lens and starts results exploration
2
Personalization of lenses and results based on user interaction
Personalized Re-Ranking of Concept Lenses
Results re-ranking and query expansion based on the selection
3
Result Categories:
Tourist Attraction
Horseback Riding
Tourism
Golf
Mountain
Walking Generic
National Park
Bar Place
Hotel Organization
Bed And Breakfast
Hamburger Sandwich
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★★★★★ 2,685 reviews and photos of 60 things to do in Killarney, Ireland.... RANK:11
More Results
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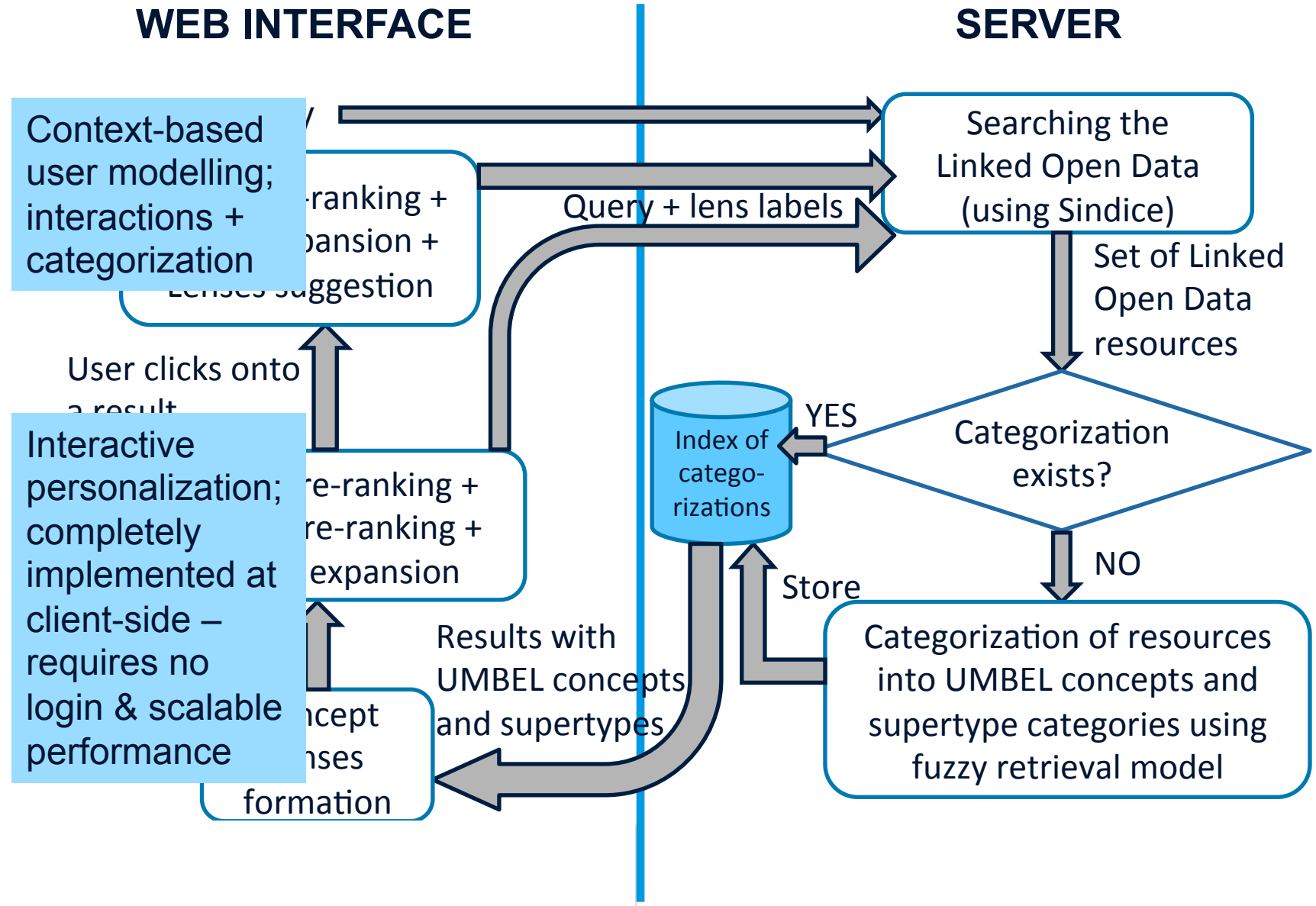
The Architecture and Workflow



Personalised Concept Based Search

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- Unique personalized concept-based search
- Results categorization as a tool for personalized lenses/results re-ranking & query expansion.
- Personalization occurs:
  - When a user selects a concept lens; all lenses are re-organized, relevant results are included and relevant lenses are suggested
  - When a user clicks onto a result; using interactive personalization. Last *N* clicks of the users within a search session are used to add relevant results
- Non-intrusive, privacy preserving and scalable,
  - No user login required and personalization on client-side
- Adaptable and can be plugable into any LOD search engine
- Only requires UMBEL categorizations that is achieved by our fuzzy retrieval model

Categorization of LOD Resources (Results) using UMBEL

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- What is UMBEL?
  - A broad conceptual vocabulary!
  - Simpler version of OpenCyc, which is manually developed over 20 years
  - Provides coherent hierarchy of 25,000 broad concepts

- Why UMBEL?
  - Coherent hierarchy of concepts
  - 32 top-level Supertype – good for organization of results
  - Alternative labels (synonyms, alternate names, etc.) – good for matching
  - Connected to linked datasets OpenCyc, DBpedia, schema.org, GeoNames – can be used for further results display, e.g. Google maps, DBpedia definition/links, etc.

How Categorization Works

- Extract semantic information from LOD resources and match to UMBEL descriptions using a fuzzy retrieval model.
  - label+type & label+type+subject provide the best results (see ESWC paper Sah & Wade 2012)
  - Categorization can be applied offline or dynamically. For scalability, new LOD resources are incrementally categorized and indexed
- A resource may match to any concept in 5-depth UMBEL hierarchy (~25,000 concepts), which is different from the general personalized search approaches
  - Generally top 1-2 levels are used but it can model only general user interests
  - In our approach, specific *UMBEL concept* matches can be used to understand user's *specific interests* (e.g. Winter Sports, Skiing) and *Supertype concepts* can be used to understand user's *general interests* (e.g. Sports)

Represent Results with UMBEL Concepts and Syntactic Information

- Each result is associated with a set of UMBEL concepts, their Supertypes and terms (textual content extracted from abstract and labels – stop words removed, terms are stemmed)
- We use vector space representation to represent this information
  - Allows scalable performance
  - Allows robust and efficient similarity measure for personalized lenses/results re-ranking;
  - Thus each result contains a vector of concepts, Supertypes and terms; for scalability we process the top *K* results (*K* = 100)
- We use only hierarchical relationships (vector of Supertype) since UMBEL does not contain semantic relatedness relations between concepts
- We alleviate this issue to an extend by
  - Extracting data from subject of LOD resources, e.g. Both Pope and Vatican resources may share Christianity and Catholic subjects
  - To include semantically related subjects, we associate each LOD resource with 1-3 UMBEL concepts and their Supertype categories. *Semantically related subjects share more concepts and Supertypes*. Only the most confident categorization is used for concept lenses formation

Typical approaches to User Data Gathering

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- Sources: Relevance feedback, implicit relevance feedback, desktop data, social Web or user's context
- Relevance feedback requires time. Desktop data/social web data often contains enough information about general user interests
  - Relying on all past interests is trick. It requires identification of subset of interests and a timeline, e.g. a user is not interested in Florence hotels after booking a room
  - In long-term user profiling, usually server-side login & storage requires – privacy issues. In client-side storage, the user profile may be dislocated to multiple access devices
- In the context-based user modeling, only the current available information within the current search context is utilized (i.e. query, query context, clicked results, etc.).
  - Benefit: System only deals with few number of interests hence performance is scalable
  - Drawback: Past interests are lost but not all past interests are useful or identification of related interests can be challenging

Our Context-based User Modelling

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- Only click data within the current search session is used
- The system copes with changes of search domain from categorization;
  - In a refined query, probable that similar concepts/supertypes will occur in new results
  - If the search topic changes completely, categorization in ~25,000 UMBEL concepts will not be the same. Fortunately, supertypes can be used to understand general interests
  - By analyzing the last *N* clicks on concepts/supertype concepts and the system can find similar LOD resources that share related concepts
- We represent user's information need using; vector of concepts (specific interests), vector of Supertypes (broad interests) & vector of terms (term interests)
- For user profiling, we track clicks onto: (i) concept lenses – personalization based on user's local choices & (ii) last *N* results – interactive personalization
  - User's interest to concept lenses; all results under a lens combined to create vectors of concepts, Supertypes & terms. We use frequency as weight to compute the shared information between lenses

$$\sum_{z=1}^{m} l_z = \sum_{i=1}^{n}\sum_{j=1}^{k} r_i c_j \rightarrow Vc(\vec{l_z}) = (w(c_1,l_z), w(c_2,l_z),\ldots, w(c_t,l_z))$$

  - For interactive personalization, we capture the user's information need as vectors of concepts, Supertypes and terms from the last N clicks (similar as concept lenses)

Re-Organization of Concept Lenses

- Personalisation (reordering) of concept lenses based on the user's local choices. Thus, conceptually relevant concept lenses move to the top of the list
- Compare similarity of the selected lens to other concept lenses using the cosine similarity of concept, Supertype and term vectors:

$$sim(l_1, l_2) = \vec{V_1}(l_1).\vec{V_2}(l_2) / |\vec{V_1}(l_1)||\vec{V_2}(l_2)|$$

- Concept similarity: If lenses share specific concepts, it is more likely they are relevant
- Supertype similarity: Computes shared broad concepts, e.g. "mountain" and "lake"
- Term similarity: Syntactic similarity. Can be noisy but guarantee some level of similarity

Re-Organization of Concept Lenses (cont.)

- Evaluations showed that the concept vector similarity alone provided the best precision. The best results were obtained when all similarity measures were combined (combined semantic and syntactic similarity).

- Lenses are displayed in decreasing relevance order

Results Re-Ranking and Concept Lenses Suggestion

- We apply results re-ranking in two cases:
  - (a) when the user selects a concept lens from the results list for exploration
  - (b) when the user clicks onto a result (LOD resource) within a concept lens
- In both cases, re-ranked results are included within the interacted concept lens. This allows in-context exploration of more results
- In case (a), we compare concept vector of the selected concept lens with the top *K* results (*K*=100)
  - We compare concept vectors since results matching at specific concepts are more likely to be relevant compared to supertype or term similarities (we only have user's interest for a concept lens). Results are added in decreasing order, a threshold can be used
- In case (b), we use the click history of the user. User's specific concept, supertype and term interests (from the last *M* results clicks) are compared with top *K* result vectors (*K*=100);

$$\sum_{i=1}^{K} \frac{\alpha * sim(\vec{Vc}(r_i), \vec{Vc}(u)) + \beta * sim(\vec{Vsc}(r_i), \vec{Vsc}(u)) + \delta * sim(\vec{Vt}(r_i), \vec{Vt}(u))}{\alpha + \beta + \delta}$$

- If a relevant result belongs to another concept, then the concept lens is suggested

Query Refinement

- Query adaptation is applied in two cases:
  - When the user selects a concept lens from the results list for exploration
  - When the last two consecutive result clicks share the same concept
- We expand the original query with the concept label the user interested
- It is a simple approach, but works well since UMBEL categorizations provide specific concept names to clarify the meaning of the query with the user feedback
- In both cases, more results are included in the context of the interacted concept lens, so that the user can explore more relevant results in context

Evaluations

- In traditional IR, there are public benchmarks (e.g. TREC) but no standard evaluation benchmarks for semantic search evaluations
- Created a benchmark dataset using LOD resources, which is available for validation and comparison, https://www.scss.tcd.ie/melike.sah/tourismdataset.zip
- We measured personalized search efficacy using precision @top *M* concept lenses and @top *N* results
  - We focused on precision for top M concept lenses & N resullts to measure improved precision for top results/ lenses

Dataset for Evaluation

- For evaluation we chose tourism domain, which suits well for data gathering and results exploration
- Indexed a particular dataset for stable and comparative evaluations
  - Popular search queries were investigated from Google Trends and searched over the WoD using Sindice to gather URIs
  - ~500 URIs from DBpedia, GeoNames, Trip Advisor and ookaboo
  - RDF descriptions, their UMBEL/supertype categorizations were indexed offline by the proposed fuzzy retrieval model to carry the experiments
  - We selected 20 queries, (no navigational queries). Such small size queries have been used before to determine indicative results in semantic search
  - Top concept lenses and results returned by the queries, were manually assigned relevant or irrelevant based on search intent. The same dataset was used for non-adaptive baseline system

Example Queries from the Dataset

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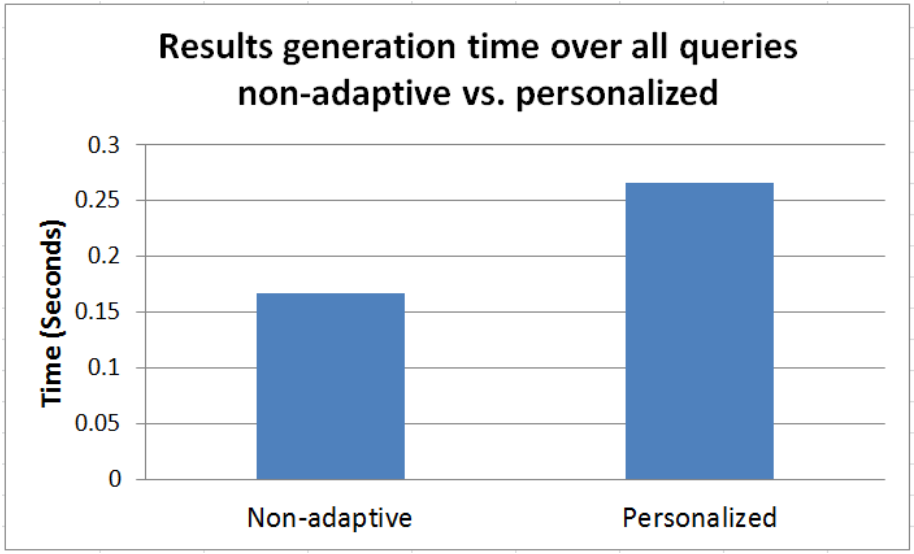
killarney sightseeing
killarney waterfall
killarney park things to do
killarney lake
killarney mountain
killarney outdoor activities
killarney island
killarney irish food
killarney bar pub
ring of kerry
……

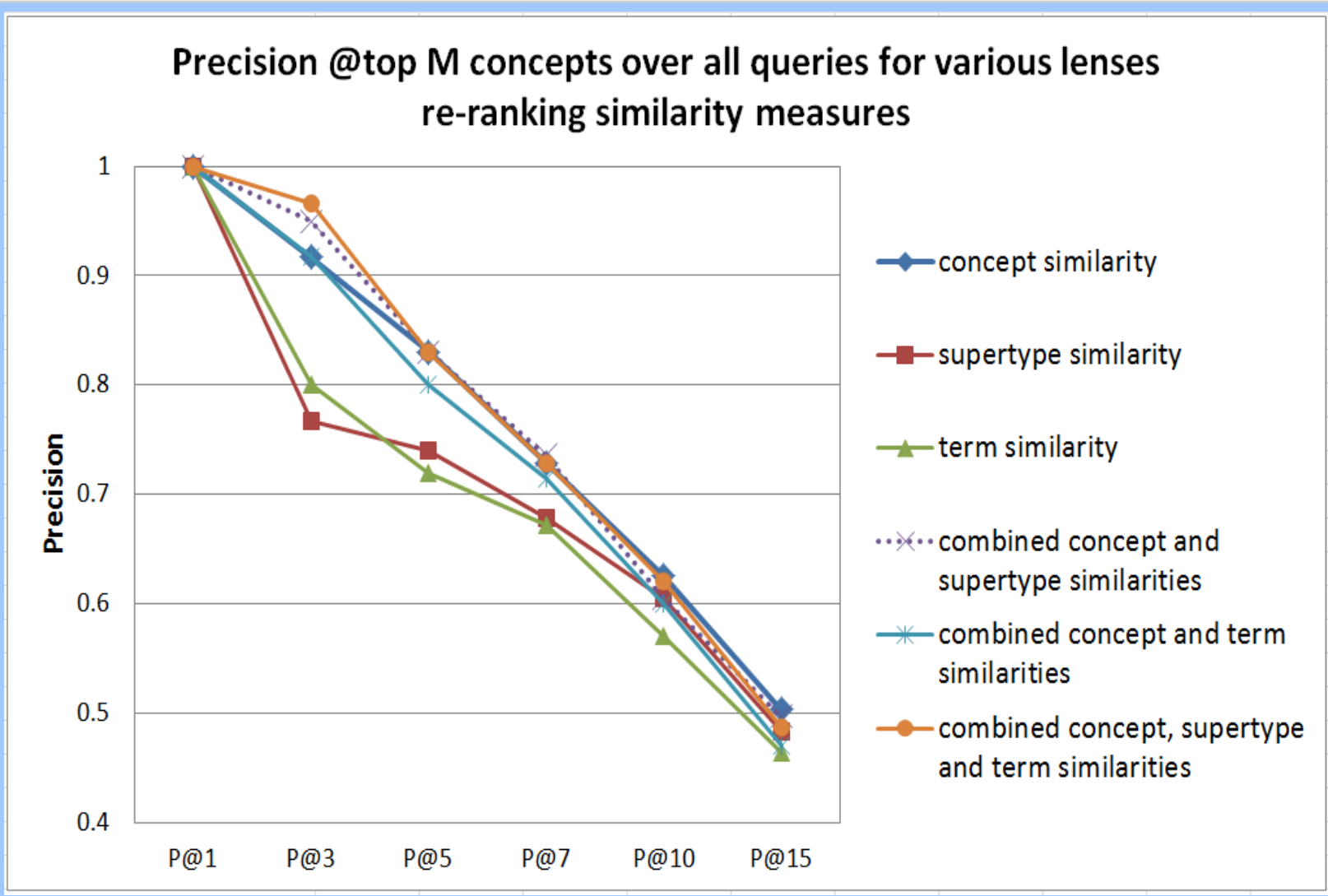
e.g. Search Intent is finding tourist attractions in the area

Personalization Time Overhead

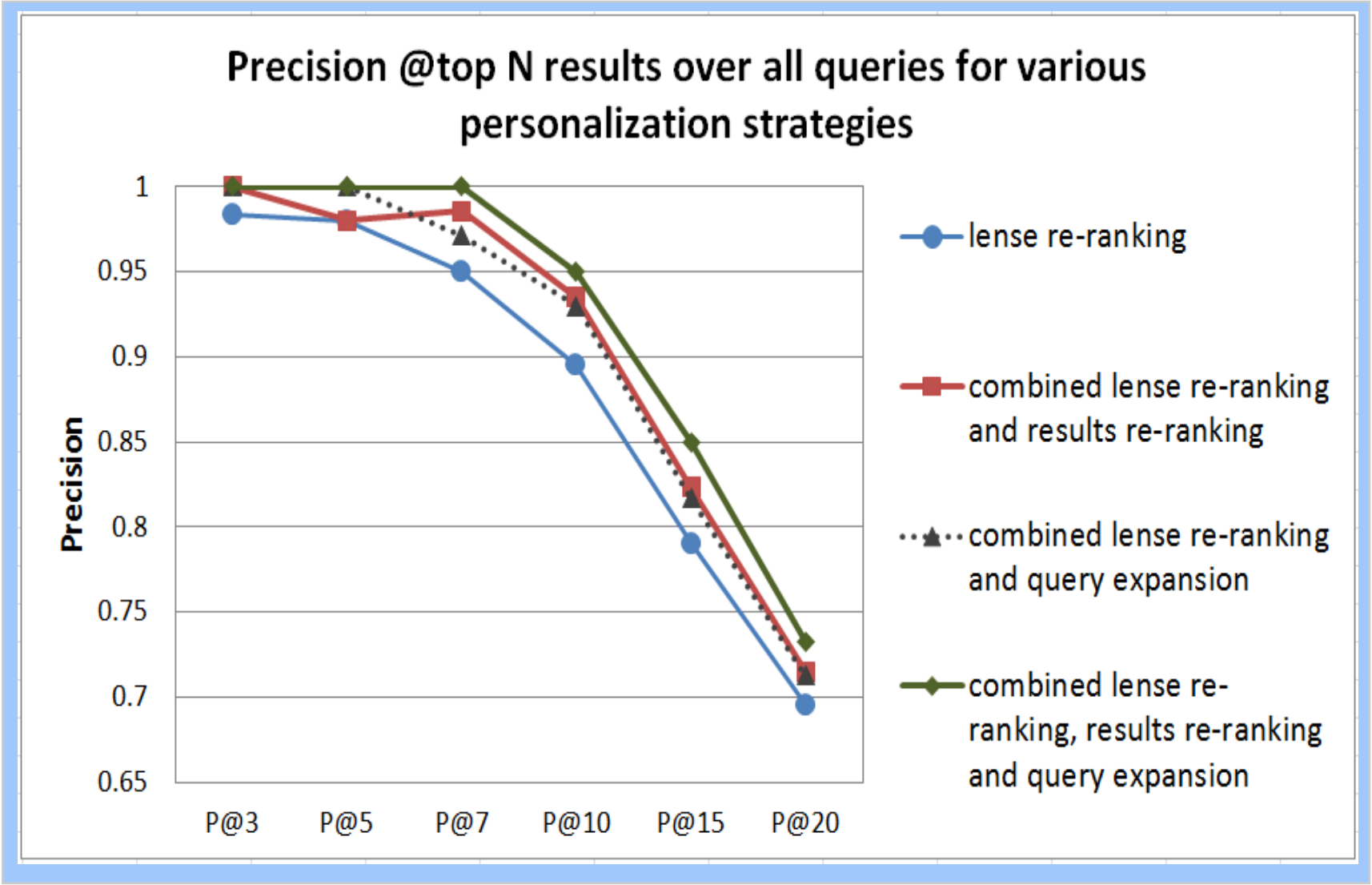
- Most LoD result categorization happens apriori. Thus, we computed dynamic average time required to generate personalized results, i.e. lenses re-organization, results re-ranking and query expansion following a lens selection
- For each query, average of 5 runs used. Experiments run on Windows 7 computer, 2.2GHz CPU and 7.90GB RAM
-



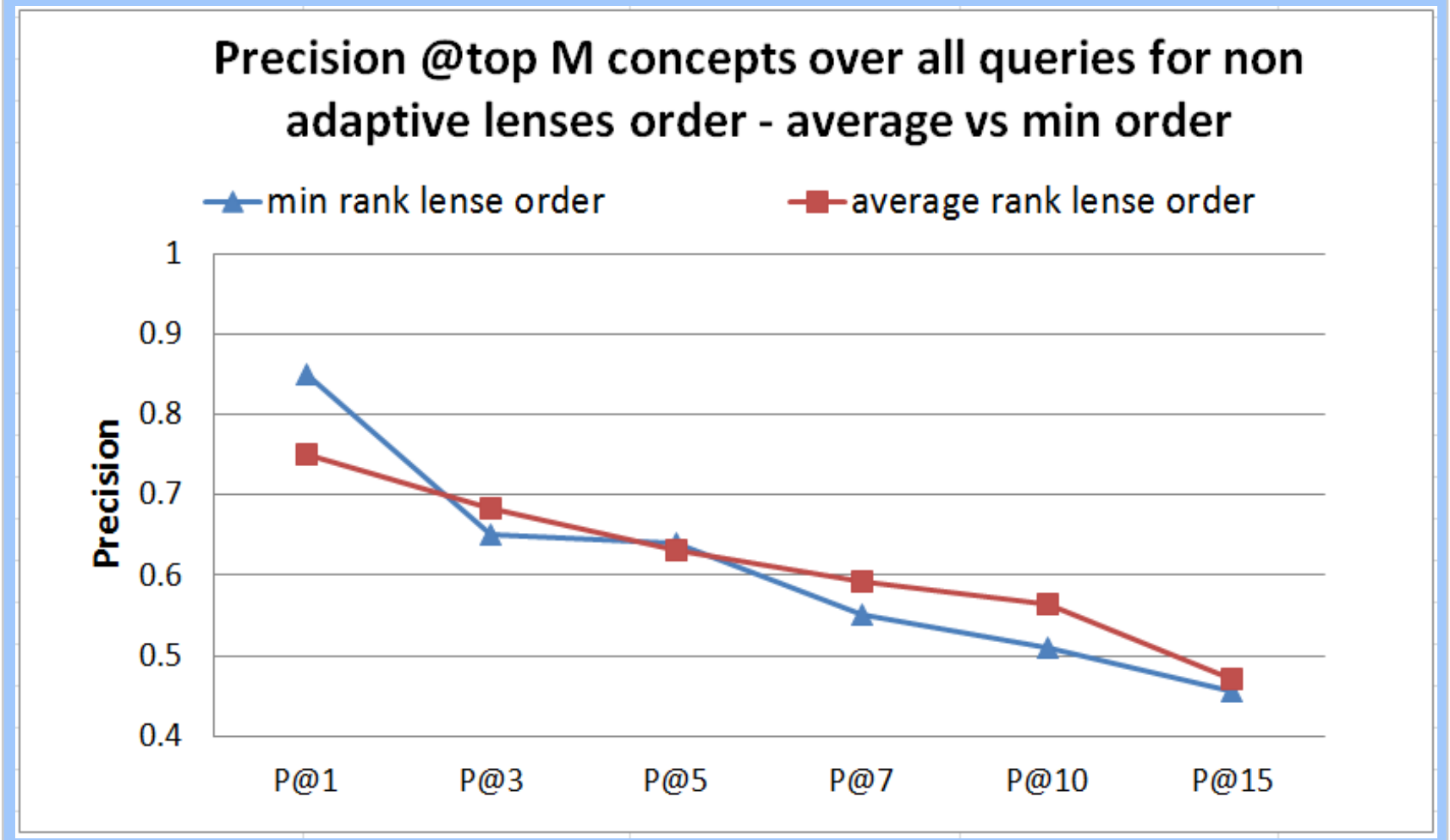
Lens Re-Ranking: Precision @top M Concepts



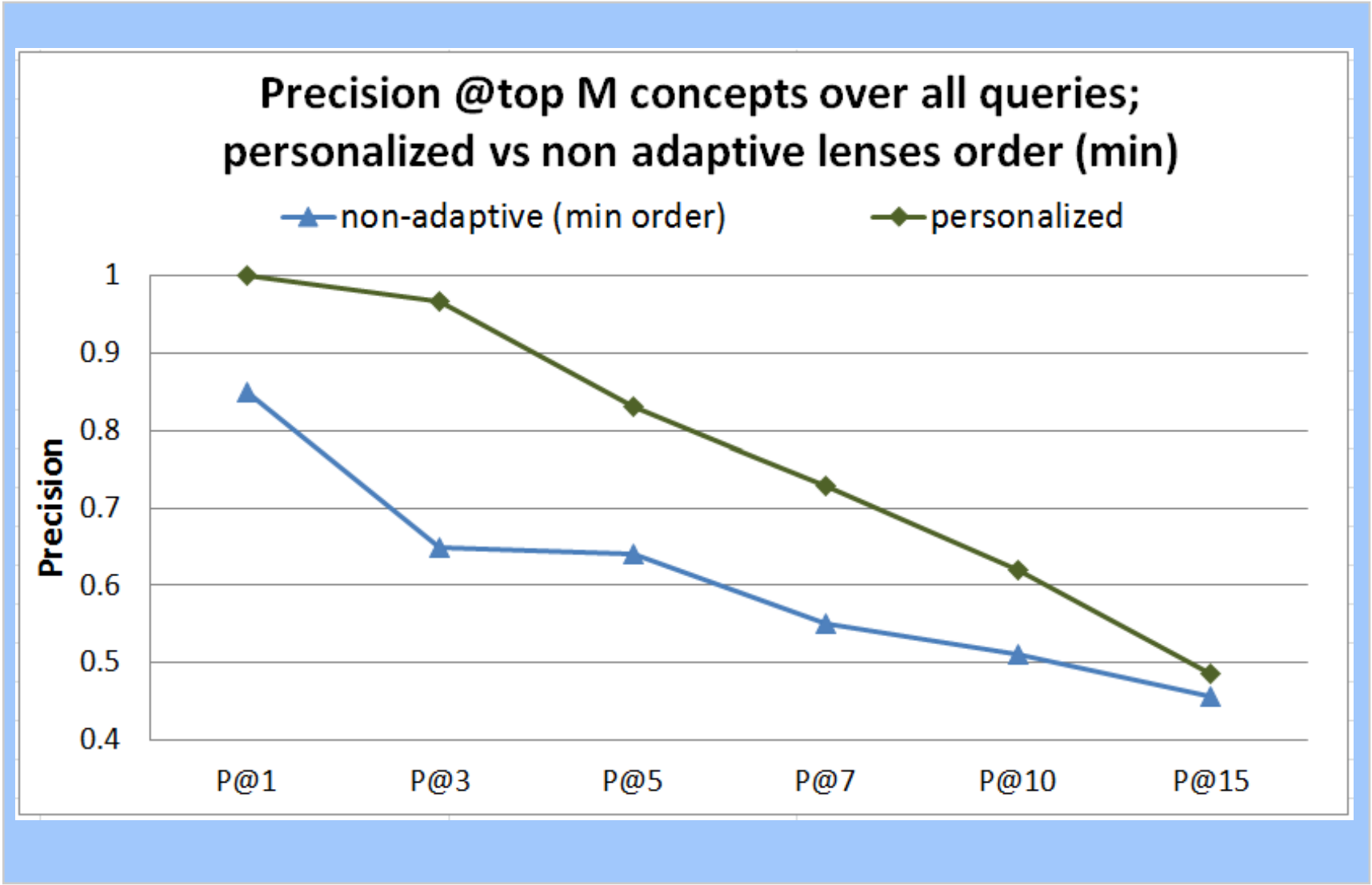
Result Personalisation: Precision @top N



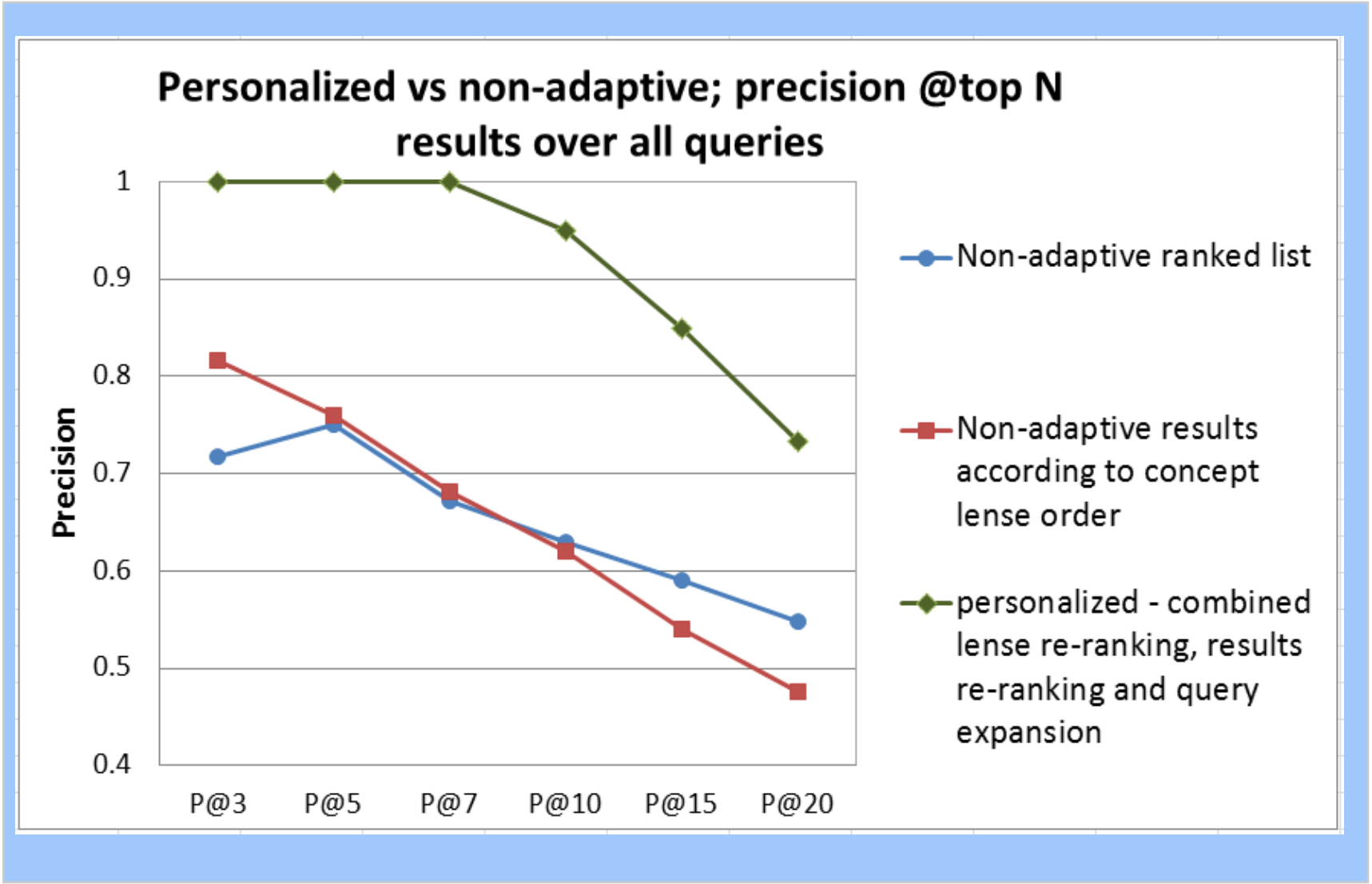
Avergage vs Min order
Precision @top M Concepts



Comparison of Non Personalised vs Personalised Concept Re-ranking Precision @top M Concepts



Comparison of Personalised vs Non Personalised Result Reranking Precision over all queries Precision @ top N Results



Conclusions and Future Work

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Indicative results

- Novel concept-based personalized search and exploration mechanism for the Web of Data
  - Results categorization as the basis of personalized concept lenses re-ordering, results re-ranking and query expansion
  - Our personalization approach is non-intrusive, privacy preserving and scalable
  - Proposed approach is adaptable and can be plugged on top of any LOD search engine
- Evaluation of Personalized concept-based search outperformed ranked list and non-adaptive concept-based search but further, larger performance & user evaluation trials are required

Future Work

- Perform scaled user studies to evaluate usability of our approach
- Data quality, trust and graph popularity can be considered in rankings

Thank You, Questions?

Contact:

Vincent.Wade@TCD.IE

Supplementary Slides

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