

Performance Evaluation of IR Systems

CS4422/7263 Information Retrieval Lecture 04

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Example – Result Table 1

| Models | Tmall | | | | Diginetica | | | | 30music | | | |
|----------------------|---------------|---------------|---------------|---------------|--------------|--------------|---------------|--------------|---------------|---------------|---------------|---------------|
| | P@10 | MRR@10 | P@20 | MRR@20 | P@10 | MRR@10 | P@20 | MRR@20 | P@10 | MRR@10 | P@20 | MRR@20 |
| FPMC | 13.10 | 7.12 | 16.06 | 7.32 | 15.43 | 6.20 | 26.53 | 6.95 | 1.51 | 0.55 | 2.40 | 0.61 |
| GRU4REC | 9.47 | 5.78 | 10.93 | 5.89 | 17.93 | 7.33 | 29.45 | 8.33 | 15.91 | 10.46 | 18.28 | 10.95 |
| NARM | 19.17 | 10.42 | 23.30 | 10.70 | 35.44 | 15.13 | 49.70 | 16.17 | 37.81 | 25.95 | 39.40 | 26.55 |
| STAMP | 22.63 | 13.12 | 26.47 | 13.36 | 33.98 | 14.26 | 45.64 | 14.32 | 36.13 | 25.97 | 42.57 | 26.27 |
| SR-GNN | 23.41 | 13.45 | 27.57 | 13.72 | 36.86 | 15.52 | 50.73 | 17.59 | 36.49 | <u>26.71</u> | 39.93 | <u>26.94</u> |
| GCE-GNN | 29.19 | 15.55 | 34.35 | 15.91 | 41.54 | 18.29 | <u>54.64</u> | 19.20 | 39.93 | 21.21 | 44.71 | 21.55 |
| S ² -DHCN | 26.22 | 14.60 | 31.42 | 15.05 | 41.16 | 18.15 | 53.18 | 18.44 | <u>40.05</u> | 17.58 | <u>45.49</u> | 17.97 |
| COTREC | <u>30.62</u> | <u>17.65</u> | <u>36.35</u> | <u>18.04</u> | 41.88 | 18.16 | 54.18 | 19.07 | 39.88 | 17.42 | 45.15 | 17.79 |
| MGS | 35.39* | 18.15* | 42.12* | 18.62* | <u>41.80</u> | <u>18.20</u> | 55.05* | <u>19.13</u> | 41.51* | 27.67* | 46.46* | 28.01* |

Evaluation metrics: P@n, MRR

¹table from SIGIR '22 "An Attribute-Driven Mirror Graph Network for Session-based Recommendation"

Example – Result Table 2

| Datasets | Models | NDCG@N | | | MAP@N | | | Recall@N | | |
|-----------|------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| | | N = 1 | N = 3 | N = 5 | N = 1 | N = 3 | N = 5 | N = 1 | N = 3 | N = 5 |
| Coat | MF [17] | 0.3748 | 0.3441 | 0.3714 | 0.1346 | 0.2100 | 0.2566 | 0.1346 | 0.2592 | 0.3705 |
| | UAE [41] | 0.3610 | 0.3546 | 0.3815 | 0.1265 | 0.2165 | 0.2648 | 0.1265 | 0.2785 | 0.3869 |
| | IAE [41] | 0.3655 | 0.3560 | 0.3812 | 0.1311 | 0.2185 | 0.2651 | 0.1311 | 0.2769 | 0.3847 |
| | RelMF [39] | 0.3959 | 0.3659 | 0.3922 | 0.1484 | 0.2281 | 0.2758 | 0.1484 | 0.2819 | 0.3926 |
| | AT [37] | 0.4017 | 0.3652 | 0.3912 | 0.1517 | 0.2286 | 0.2753 | 0.1517 | 0.2772 | 0.3908 |
| | PD [61] | 0.3997 | 0.3543 | 0.3737 | 0.1433 | 0.2182 | 0.2606 | 0.1433 | 0.2622 | 0.3627 |
| | MACR [54] | 0.4176 | 0.3798 | 0.3973 | 0.1559 | 0.2389 | 0.2834 | 0.1559 | 0.2875 | 0.3870 |
| | CJMF [†] [63] | 0.4093 | 0.3856 | 0.4097 | 0.1500 | 0.2408 | 0.2900 | 0.1500 | 0.2984 | 0.4075 |
| | BISER (ours) | 0.4503* | 0.4109* | 0.4378** | 0.1725* | 0.2663** | 0.3192** | 0.1725* | 0.3185* | 0.4367** |
| | Gain (%) | 10.03 | 6.56 | 6.85 | 14.99 | 10.58 | 10.08 | 14.99 | 6.74 | 7.16 |
| Yahoo! R3 | MF [17] | 0.1797 | 0.2081 | 0.2411 | 0.1071 | 0.1688 | 0.1970 | 0.1071 | 0.2225 | 0.3040 |
| | UAE [41] | 0.1983 | 0.2235 | 0.2532 | 0.1198 | 0.1836 | 0.2104 | 0.1198 | 0.2362 | 0.3111 |
| | IAE [41] | 0.2137 | 0.2355 | 0.2653 | 0.1309 | 0.1956 | 0.2232 | 0.1309 | 0.2461 | 0.3211 |
| | RelMF [39] | 0.1837 | 0.2122 | 0.2453 | 0.1102 | 0.1728 | 0.2014 | 0.1102 | 0.2266 | 0.3080 |
| | AT [37] | 0.1912 | 0.2179 | 0.2506 | 0.1149 | 0.1786 | 0.2071 | 0.1149 | 0.2310 | 0.3125 |
| | PD [61] | 0.1994 | 0.2308 | 0.2647 | 0.1211 | 0.1901 | 0.2207 | 0.1211 | 0.2459 | 0.3297 |
| | MACR [54] | 0.2044 | 0.2274 | 0.2571 | 0.1243 | 0.1882 | 0.2154 | 0.1243 | 0.2382 | 0.3133 |
| | CJMF [†] [63] | 0.2151 | 0.2426 | 0.2715 | 0.1320 | 0.2018 | 0.2291 | 0.1320 | 0.2564 | 0.3297 |
| | BISER (ours) | 0.2323** | 0.2608** | 0.2894** | 0.1446** | 0.2195** | 0.2479** | 0.1446** | 0.2748** | 0.3477** |
| | Gain (%) | 7.99 | 7.52 | 6.60 | 9.58 | 8.77 | 8.20 | 9.58 | 7.18 | 5.47 |

Evaluation metrics: **NDCG, MAP, Recall**

¹Table from SIGIR '22 "Bilateral Self-unbiased Learning from Biased Implicit Feedback"

Example – Result Table 3

Table 3: Results of stance detection.

| Dataset | RumourEval2019-S | | | | | | | SemEval8 | | | | | | |
|--------------------|------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Method | AUC | MicF | MacF | S | D | Q | C | AUC | MicF | MacF | S | D | Q | C |
| | | | | F_1 | F_1 | F_1 | F_1 | | | | F_1 | F_1 | F_1 | F_1 |
| Zero-Shot | — | 0.369 | 0.324 | 0.301 | 0.168 | 0.342 | 0.486 | — | 0.383 | 0.344 | 0.278 | 0.162 | 0.480 | 0.456 |
| Pre-Rule | — | 0.605 | 0.478 | 0.657 | 0.419 | — | — | — | 0.429 | 0.389 | 0.432 | 0.644 | — | — |
| C-GCN | 0.633 | 0.629 | 0.416 | 0.331 | 0.173 | 0.429 | 0.730 | 0.610 | 0.625 | 0.411 | 0.327 | 0.161 | 0.430 | 0.728 |
| BrLSTM(V) | 0.710 | 0.660 | 0.420 | 0.460 | 0.000 | 0.391 | 0.758 | 0.676 | 0.665 | 0.401 | 0.493 | 0.000 | 0.381 | 0.730 |
| BiGRU(V) | 0.700 | 0.630 | 0.417 | 0.392 | 0.162 | 0.360 | 0.754 | 0.660 | 0.633 | 0.416 | 0.460 | 0.168 | 0.328 | 0.708 |
| MT-GRU(V) | 0.714 | 0.636 | 0.432 | 0.313 | 0.156 | 0.506 | 0.748 | 0.669 | 0.630 | 0.413 | 0.498 | 0.116 | 0.312 | 0.729 |
| TD-MIL(V) | 0.712 | 0.650 | 0.432 | 0.438 | 0.156 | 0.408 | 0.688 | 0.668 | 0.626 | 0.416 | 0.473 | 0.127 | 0.463 | 0.602 |
| BU-MIL(V) | 0.710 | 0.630 | 0.431 | 0.485 | 0.166 | 0.396 | 0.688 | 0.669 | 0.623 | 0.415 | 0.470 | 0.128 | 0.460 | 0.602 |
| TD-MIL(T15) | 0.706 | 0.668 | 0.427 | 0.339 | 0.173 | 0.444 | 0.752 | 0.663 | 0.642 | 0.418 | 0.330 | 0.174 | 0.420 | 0.750 |
| TD-MIL(T16) | 0.713 | 0.665 | 0.436 | 0.350 | 0.182 | 0.446 | 0.758 | 0.660 | 0.671 | 0.421 | 0.334 | 0.173 | 0.422 | 0.754 |
| TD-MIL(PHE) | 0.722 | 0.691 | 0.434 | 0.344 | 0.179 | 0.467 | 0.767 | 0.669 | 0.651 | 0.426 | 0.335 | 0.175 | 0.430 | 0.763 |
| BU-MIL(T15) | 0.706 | 0.662 | 0.428 | 0.341 | 0.173 | 0.436 | 0.756 | 0.661 | 0.638 | 0.415 | 0.326 | 0.168 | 0.420 | 0.748 |
| BU-MIL(T16) | 0.701 | 0.660 | 0.426 | 0.340 | 0.170 | 0.438 | 0.749 | 0.659 | 0.637 | 0.416 | 0.324 | 0.169 | 0.419 | 0.753 |
| BU-MIL(PHE) | 0.707 | 0.665 | 0.432 | 0.344 | 0.174 | 0.445 | 0.762 | 0.666 | 0.642 | 0.420 | 0.329 | 0.169 | 0.423 | 0.758 |

Evaluation metrics: AUC, MicF, MacF, F1

¹Table from SIGIR '22 "A Weakly Supervised Propagation Model for Rumor Verification..."

Example – Result Table 4

| Training Domains | Query Domain | Methods | ZSL | | GZSL | |
|---|--------------|--------------------|---------------|---------------|---------------|---------------|
| | | | mAP@200 | Prec@200 | mAP@200 | Prec@200 |
| Real, Sketch Infograph, Painting Clipart | Sketch | EISNet [49] | 0.3719 | 0.3136 | 0.3355 | 0.2822 |
| | | CuMix [31] | 0.3689 | 0.3069 | 0.3300 | 0.2714 |
| | | SnMpNet [34] | 0.4221 | 0.3496 | 0.3767 | 0.3109 |
| | | SASA (Ours) | 0.5487 | 0.4655 | 0.4865 | 0.4146 |
| Real, Quickdraw Infograph, Painting Clipart | Quickdraw | EISNet [49] | 0.2475 | 0.1906 | 0.2118 | 0.1627 |
| | | CuMix [31] | 0.2546 | 0.1967 | 0.2177 | 0.1699 |
| | | SnMpNet [34] | 0.2888 | 0.2314 | 0.2366 | 0.1918 |
| | | SASA (Ours) | 0.3819 | 0.2993 | 0.3118 | 0.2488 |

Evaluation metrics: mAP, Prec

¹Table from SIGIR '22 "Structure-Aware Semantic-Aligned Network..."

1 What do we evaluate?

2 Evaluation Metrics

- Binary assessment
- Rank-based measures
- Diagnostic Tools
- Beyond Binary Relevance: NDCG

3 Test Collections and the Cranfield Paradigm

4 Online Evaluation

IR Evaluation

- How do we compare these search engines? How do we evaluate the IR systems behind?
 - ▶ How are the results relevant to the user query?
 - ▶ How fast does it search?
 - ▶ How fast does it index (update contents)?
 - ▶ Is the result presented effectively?
- In this lecture, we will mainly focus on the retrieval effectiveness
 - ▶ How good an IR system retrieve relevant items to the user's information need.

IR Evaluation (Cont.)

- Note: **user need** is translated into a **query**
- Relevance is assessed relative to the user need, not the query
- E.g.,
 - ▶ Query: *“pool cleaner”*
 - ▶ Information need: *[My swimming pool bottom is becoming black and needs to be cleaned]*
- Assess whether the doc addresses the underlying need, not whether it has these words

Precision and Recall

- The relevance of a document to a query is **subjective**.
- We need precise definition of “**relevance**” and quantitative evaluation metrics.
- How can we evaluate the retrieval performance?
 - ▶ Manual vs. Automatic

| rank | model A | model B |
|------|----------|---------|
| 1 | 87641 | 1851596 |
| 2 | 57182758 | 8722556 |
| 3 | 6165392 | 13769 |
| 4 | 157692 | 2910525 |
| 5 | 878262 | 37619 |
| 6 | 4718 | 995166 |

Table: Two ranked list of documents, Which are better?

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Confusion Matrix – Binary Assessment

- Confusion matrix is a table that shows the performance of a supervised learning model.
 - ▶ Each row represents the **ground truth class** assignments,
 - ▶ while each column represents the **predicted classes**, or vice versa.

| | Retrieved | Non Retrieved |
|--------------|---------------------|---------------------|
| Relevant | True Positive (TP) | False Negative (FN) |
| Not Relevant | False Positive (FP) | True Negative (TN) |

Precision

- Precision is the fraction of retrieved documents that were relevant.

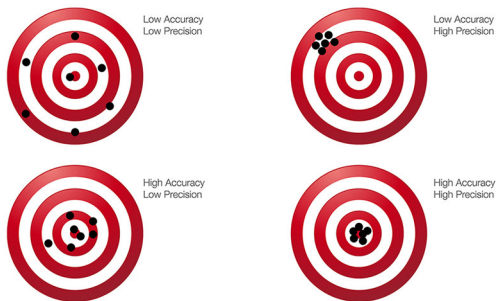
$$\begin{aligned} prec. &= \frac{|\text{retrieved and relevant}|}{|\text{retrieved}|} \\ &= \frac{TP}{TP + FP} \end{aligned}$$

Recall

- Recall is the fraction of relevant documents retrieved by the system.

$$\begin{aligned} prec. &= \frac{|\text{retrieved and relevant}|}{|\text{relevant}|} \\ &= \frac{TP}{TP + FN} \end{aligned}$$

Precision vs. Accuracy



- **Precision** is how close/dispersed the measurements are **to each other**.
- **Accuracy** is how close or far off a given set of measurements are **to their true value**. **Accuracy in Binary Classification?**

Precision and Recall

- Suppose the total number of relevant documents is 10
- Green's are TPs; predicted "relevant" and that is correct
- Red's are FPs; predicted "relevant" and that is incorrect
- What are the precision and recall of the models?

| rank | model A | model B |
|------|----------|---------|
| 1 | 87641 | 1851596 |
| 2 | 57182758 | 8722556 |
| 3 | 6165392 | 13769 |
| 4 | 157692 | 2910525 |
| 5 | 878262 | 37619 |
| 6 | 4718 | 995166 |

F-score

- **F-Measure** combines both recall and precision, so systems that favor are penalized for whichever is lower.

$$F_{\beta} = (1 + \beta^2) \cdot \frac{\text{precision} \cdot \text{recall}}{(\beta^2 \cdot \text{precision}) + \text{recall}}$$

- Commonly used F-Measure is the F1 score, where $\beta = 1$

$$F_1 = 2 \cdot \frac{\text{precision} \cdot \text{recall}}{\text{precision} + \text{recall}}$$

- What are the F1 scores of the model A and B?

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Rank-based Measures

- Precision/Recall/F-1 are set-based measures
- Now, we will discuss **rank-based measures**
- Binary relevance
 - ▶ precision@K (P@K)
 - ▶ Mean Average Precision (MAP)
 - ▶ Mean Reciprocal Rank (MRR)
- Multiple levels of relevance
 - ▶ Normalized Discounted Cumulative Gain (NDCG)

P@K: Precision at K

- **Precision at K** corresponds to the number of relevant results among the top K retrieved documents
 - 1 set a rank threshold k
 - 2 compute the percentage of relevant in top k
 - 3 ignore documents ranked lower than k
- Model A: $P@5 = 2/5 = .4$
- Model B: $P@5 = 2/5 = .4$

| rank | model A | model B |
|------|----------|---------|
| 1 | 87641 | 1851596 |
| 2 | 57182758 | 8722556 |
| 3 | 6165392 | 13769 |
| 4 | 157692 | 2910525 |
| 5 | 878262 | 37619 |
| 6 | 4718 | 995166 |

What are the shortcomings of *precisionK* measure?

AP: Average Precision

- It is desirable to also consider the order (i.e., the positions of the relevant documents) in which the returned documents are presented.
- Average precision computes the average value of **precision at K scores**.

$$AP(\vec{r}, n) = \frac{1}{R} \sum_{k: \vec{r}_k=1} P@K(\vec{r}, k)$$

Average Precision – Example

| rank | model A | P@K | AP |
|------|----------|-----|----|
| 1 | 87641 | | |
| 2 | 57182758 | | |
| 3 | 6165392 | | |
| 4 | 157692 | | |
| 5 | 878262 | | |
| 6 | 4718 | | |
| 7 | 957174 | | |
| 8 | 5827561 | | |

- Suppose $\vec{r} = (0, 1, 1, 0, 0, 0, 1, 0)$
- Consider the rank of each relevant documents: $k_{\vec{r}_k=1} = (2, 3, 7)$

Average Precision – Example (Cont.)

| rank | model A | P@K | AP |
|------|----------|-----|-------------------|
| 1 | 87641 | 0/1 | 0 |
| 2 | 57182758 | 1/2 | (1/2) / 1 |
| 3 | 6165392 | 2/3 | (1/2+2/3) / 2 |
| 4 | 157692 | 2/4 | same as above |
| 5 | 878262 | 2/5 | same as above |
| 6 | 4718 | 2/6 | same as above |
| 7 | 957174 | 3/7 | (1/2+2/3+3/7) / 3 |
| 8 | 5827561 | 3/8 | same as above |

- Compute the $P@K$ for each k : $P@k = (1/2, 2/3, 3/7)$
- Average Precision at $k = 7$:

$$AP(\vec{r}, 7) = \frac{1}{3} \cdot \left(\frac{1}{2} + \frac{2}{3} + \frac{3}{7} \right) \approx 0.53$$

What would be the precision at K from a perfect system?

MAP: Mean Average Precision – Example

- Related metric is **Mean Average Precision (MAP)**, which is the mean of Average Precision across multiple queries/rankings.
- E.g.,
 - ▶ $AP(\vec{r}(q_1), 10) = (1.0 + 0.67 + 0.5 + 0.44 + 0.5)/5 = 0.62$
 - ▶ $AP(\vec{r}(q_2), 10) = (0.5 + 0.4 + 0.43)/3 = 0.44$

$$MAP((q_1, q_2), 10) = \frac{1}{2} \cdot (0.62 + 0.44) = 0.53$$

Mean Average Precision (Cont.)

- If a relevant document never gets retrieved, we assume the precision corresponding to that relevant doc to be zero.
- MAP is **macro-averaging**: each query counts equally.
- Now, perhaps most commonly used measure in research papers.
- Good for web search?
 - ▶ MAP assumes user is interested in finding many relevant documents for each query.
 - ▶ MAP requires many relevance judgments in text collection.

R-Precision

- **R-precision** is the precision@R where R is the number of relevant documents to the given query.
- R is used as the cutoff, which varies from query to query
 - ▶ Suppose there are 20 documents (i.e., $R = 20$) to “apple store” in a corpus.
 - ▶ If your ranking system retrieved 5 relevant documents in the top 20 list, then R-precision is $5/20 = 0.25$.
- *R-precision requires knowing all documents that are relevant to a query.*

1 What do we evaluate?

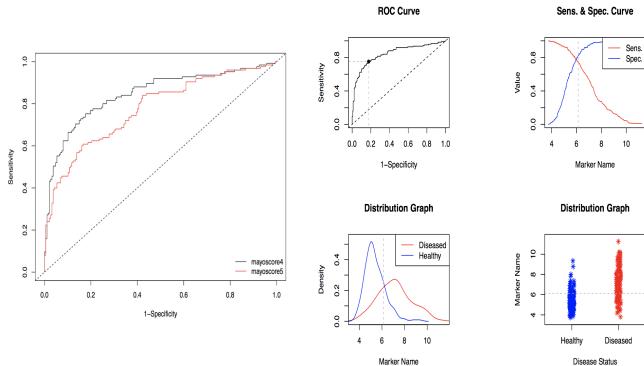
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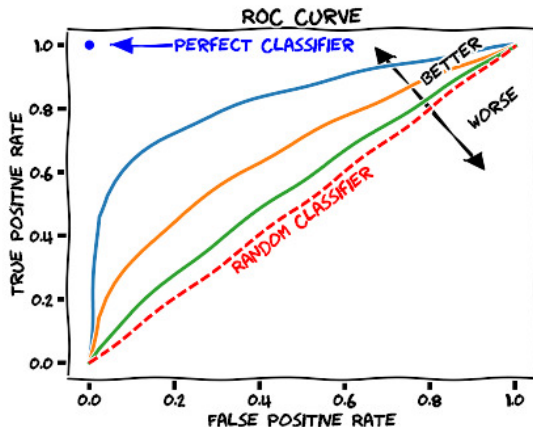
Diagnostic Tools



- In this lecture, we will discuss two diagnostic tools: **ROC Curve** and **Precision-Recall Curve**
- The area under the curve can be used to directly compare the models.

^aimage from: <http://www.biosoft.hacettepe.edu.tr/easyROC/>

ROC Curves



ROC (Receiver Operating Characteristic) curves illustrate the *relationships between correct predictions and wrong predictions on the positive class.*

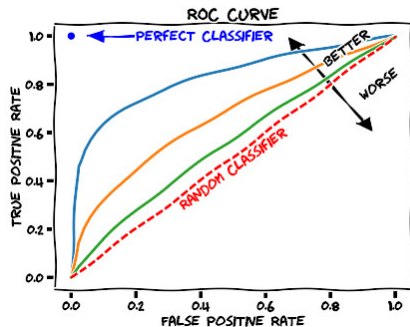
ROC Curves (Cont.)

- ROC Curves plot the **True Positive Rate** (TPR) against **False Positive Rate** (FPR).
- True Positive Rate (also called *recall*, *sensitivity*, *hit rate*).

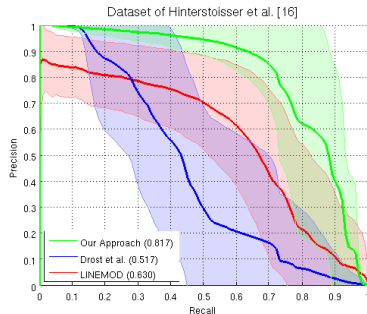
$$TPR = \frac{TP}{P} = \frac{TP}{TP + FN}$$

- False Positive Rate (also called *fall-out*)

$$FPR = \frac{FP}{N} = \frac{FP}{FP + TN}$$

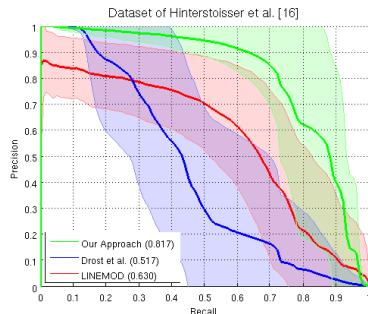


Precision-Recall Curves



- **Precision-Recall curves** illustrate the trade-off between **precision** and **recall** for every possible *discrimination threshold cut-off*.
- *What happen, if you classifier predicts everything positive? Or, vice versa?*

Precision-Recall Curves (Cont.)



- Precision-Recall is plotting the precision against recall
 - ▶ $precision = TP / (TP + FP)$
 - ▶ $recall = TP / (TP + FN)$
- Precision-Recall makes it possible to assess the performance of a model on the minority class

MRR: Mean Reciprocal Rank

- MRR considers the rank position (k) of the first relevant document – Could be the clicked website of the web search results.
- Reciprocal Rank:

$$RR = \frac{1}{k}$$

- MRR is the mean RR across multiple queries.

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Normalized Discounted Cumulative Gain (NDCG)

Normalized Discounted Cumulative Gain

Assumptions:

- Graded relevance (beyond binary): For example, in 0-3 relevance scale, we have 0-irrelevant, 1-marginally relevant, 2-fairly relevant, 3-highly relevant.
- The relevant documents ranked lower are less useful for the user, since it is less likely to be examined.

Normalized Discounted Cumulative Gain (NDCG)

Normalized Discounted Cumulative Gain

- Graded relevance is used as a measure of usefulness, or **gain**
- Gain is **accumulated** starting at the top of the ranking and may be reduced, or discounted, at lower ranks
- Typical **discount** is $1/\log(rank)$
- DCG (Discounted Cumulative Gain) is the total gain accumulated at a particular rank p :

$$DCG_p = rel_1 + \sum_{i=2}^p \frac{rel_i}{\log_2 i}$$

DCG Example

- 10 ranked documents judged on 0–3 relevance scale:
(3, 2, 3, 0, 0, 1, 2, 2, 3, 0)
- Discounted gain:
(3, 2/1, 3/1.59, 0, 0, 1/2.59, 2/2.81, 2/3, 3/3.17, 0)
= (3, 2, 1.89, 0, 0, 0.39, 0.71, 0.67, 0.95, 0)
- Discounted Cumulative Gain:
(3, 5, 6.89, 6.89, 6.89, 7.28, 7.99, 8.66, 9.61, 9.61(= DCG_{10}))

NDCG for summarizing rankings

Normalized Discounted Cumulative Gain

- Normalize DCG at rank n
 - ▶ DCG at rank n by the DCG value at rank n of the ideal ranking
- The ideal ranking would first return the documents with the highest relevance level, then the next highest relevance level, etc
- Normalization is useful for contrasting queries with varying numbers of relevant results
- **NDCG** is now quite popular in evaluating Web search

NDCG Example

Suppose we have four documents: d_1, d_2, d_3, d_4 and the relevance judgment.

| i | Ground Truth | Ranking Model A | Ranking Model B |
|---|----------------|-----------------|-----------------|
| 1 | $d_4(r_1 = 2)$ | $d_3(r_2 = 2)$ | $d_3(r_2 = 2)$ |
| 2 | $d_3(r_2 = 2)$ | $d_4(r_1 = 2)$ | $d_2(r_3 = 1)$ |
| 3 | $d_2(r_3 = 1)$ | $d_2(r_3 = 1)$ | $d_4(r_1 = 2)$ |
| 4 | $d_1(r_4 = 0)$ | $d_1(r_4 = 0)$ | $d_1(r_4 = 0)$ |

NDCG Example (Cont.)

| i | Ground Truth | Ranking Model A | Ranking Model B |
|---|----------------|-----------------|-----------------|
| 1 | $d_4(r_1 = 2)$ | $d_3(r_2 = 2)$ | $d_3(r_2 = 2)$ |
| 2 | $d_3(r_2 = 2)$ | $d_4(r_1 = 2)$ | $d_2(r_3 = 1)$ |
| 3 | $d_2(r_3 = 1)$ | $d_2(r_3 = 1)$ | $d_4(r_1 = 2)$ |
| 4 | $d_1(r_4 = 0)$ | $d_1(r_4 = 0)$ | $d_1(r_4 = 0)$ |

- Ground Truth

$$DCG_{gt} = 2 + \left(\frac{2}{\log_2 2} + \frac{1}{\log_2 3} + \frac{0}{\log_2 4} \right) = 4.6309 \quad nDCG_{gt} = 4.6309 / 4.6309 = 1$$

- Model A

$$DCG_A = 2 + \left(\frac{2}{\log_2 2} + \frac{1}{\log_2 3} + \frac{0}{\log_2 4} \right) = 4.6309 \quad nDCG_A = 4.6309 / 4.6309 = 1$$

- Model B

$$DCG_B = 2 + \left(\frac{1}{\log_2 2} + \frac{2}{\log_2 3} + \frac{0}{\log_2 4} \right) = 4.2619 \quad nDCG_B = 4.2619 / 4.6309 = 0.9203$$

MRR: Mean Reciprocal Rank

- MRR considers rank position, k , of the first relevant document; it could be the clicked website in web search scenarios.
- Reciprocal Rank score: $RR = \frac{1}{k}$
- MRR is the mean RR across multiple queries.

TREC_EVAL Example Results

| | | |
|---------------|-----|--------|
| num_q | all | 30 |
| num_ret | all | 30000 |
| num_rel | all | 3875 |
| num_rel_ret | all | 1555 |
| map | all | 0.1206 |
| gm_ap | all | 0.0614 |
| R-prec | all | 0.1906 |
| bpref | all | 0.2482 |
| recip_rank | all | 0.4924 |
| ircl_prn.0.00 | all | 0.5676 |
| ircl_prn.0.10 | all | 0.3467 |
| ircl_prn.0.20 | all | 0.2443 |
| ircl_prn.0.30 | all | 0.1773 |
| ircl_prn.0.40 | all | 0.1206 |
| ircl_prn.0.50 | all | 0.0678 |
| ircl_prn.0.60 | all | 0.0345 |
| ircl_prn.0.70 | all | 0.0194 |
| ircl_prn.0.80 | all | 0.0051 |
| ircl_prn.0.90 | all | 0.0000 |
| ircl_prn.1.00 | all | 0.0000 |
| P5 | all | 0.3933 |
| P10 | all | 0.3833 |
| P15 | all | 0.3600 |
| P20 | all | 0.3300 |
| P30 | all | 0.2933 |
| P100 | all | 0.1777 |
| P200 | all | 0.1297 |
| P500 | all | 0.0807 |

- **map**: mean average precision
- **gm_ap**: geometric mean average precision
- **R-prec**: R-precision
- **bpref**: preference-based IR measure
- **recip_rank**: reciprocal rank
- **ircl_prn**: interpolated recall – precision average at r recall
- **p@k**: precision at k

1 What do we evaluate?

2 Evaluation Metrics

- Binary assessment
- Rank-based measures
- Diagnostic Tools
- Beyond Binary Relevance: NDCG

3 Test Collections and the Cranfield Paradigm

4 Online Evaluation

User-based vs. Laboratory Evaluation

User-based Evaluation

- Assessment is performed by real users; hence it is **expensive and time-consuming**.
- One-off: The system is evaluated once.
- It is difficult to eliminate the influence of the user on the evaluation (i.e., **biases**).
- The results are often **inconsistent** between raters and over time.
- Humans judgment are not always representative of the population.

User-based vs. Laboratory Evaluation

Laboratory-based Evaluation

- Evaluation is performed in a controlled environment.
- Automated evaluation is possible; hence it is **not expensive**.
- It is faster and easier to evaluate and to replicate.
- However, it is **difficult to build a fair test collection** that is representative of the real world.

Test Collections

- To compare the performances of the IR systems
- Test collection is **a laboratory environment** that does not change in which we test and compare retrieval models
- It is wrong to report results on a test collection which were obtained by tuning the model parameters to maximize performance on the test collection.
- You should *tune* your model **on one or more development test collections** and obtain results from the test collection.

The Cranfield Paradigm

- Cyril Cleverdon (1914-1997) and his colleagues established the foundation for the evaluation of IR systems
- He started a series of projects, called **the Cranfield projects** whereby retrieval experiments were conducted on test databases in a controlled, laboratory-like setting.



Figure: A British librarian and computer scientist

The Cranfield Project

- He worked at the library of the College of Aeronautics at Cranfield, UK, in the late 1950's long before computers came around.
- The objective of his study was to find what kinds of **indexing languages** were most effective.
- **Findings:**
 - ▶ For indexing purpose, using the terms from the corpus is more effective as opposed to expert-selected topical or category terms (i.e., controlled vocabulary)
 - ▶ The inverse relationship of precision and recall

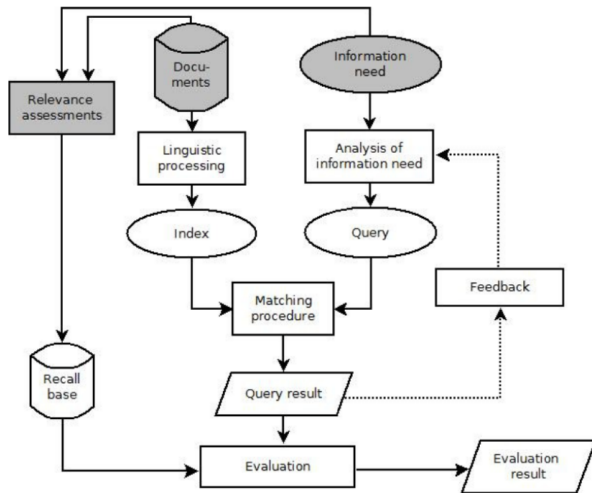
The Cranfield Paradigm – Today

- Model a real user application, with realistic information needs.
- Scale up the observational examples to allow significant testing.
- Make relevance judgments before the experiments.

Three elements of test collections

- 1 A benchmark document collection
- 2 A benchmark set of queries
- 3 An assessment of either **Relevant** or **Non-relevant** for each query and each document (Also called *relevance judgements*)

Schematic of Test Collection



TREC (Text REtrieval Conference)

- Run by the U.S. National Institute for Standards and Technology (NIST) in Maryland
- Has been a major driver of IR research and source of test collections from 1992 onward.
- Several language-specific conferences have been created internationally to follow its approach

TREC-style Conferences

| name | focus | started | recent topics |
|-------|---------------------------------------|---------|--|
| TREC | English (mainly) | 1992 | conversational assistance, deep learning, health misinformation, news, podcast, precision medicine |
| NTCIR | East Asian languages | 1999 | financial tweets, government data, Wikipedia, ad hoc web search |
| CLEF | European languages, cross-language IR | 2000 | math QA, biomedical QA, multimedia retrieval, text translation (scientific to simple text) |
| FIRE | Indian and South Asian languages | 2008 | hate speech detection, AI for legal assistant, sentiment analysis, fake news detection, causality-driven ad hoc IR |

TREC – the Precision Medicine (PM) Track

2021 TREC-PM Objective

TREC-PM focuses on **identifying high-quality evidence for a specific cancer treatment**. Each case will describe the patient's disease (type of cancer), the relevant genetic variants (which genes are mutated), and the proposed treatment. Participants of the track will be challenged with retrieving biomedical articles providing strong evidence for/against the treatment in the specific population.

Document Collections

- The MEDLINE baseline will be used for the scientific abstracts, which is a repository for biomedical and life science journal articles.

Document Collection Example

- NLM produces a baseline set of MEDLINE/PubMed citation records in XML format.

```
<?xml version="1.0"?>
<!DOCTYPE article PUBLIC "-//NLM//DTD Journal Archiving and Interchange
  DTD v2.3 20070202//EN" "archivearticle.dtd">
<article xmlns:xlink="http://www.w3.org/1999/xlink" article-type="review-article">
  <?properties open_access?>
  <front>
    <journal-meta>
      <journal-id journal-id-type="nlm-ta">Crit Care</journal-id>
      <journal-title>Critical Care</journal-title>
      <issn pub-type="ppub">1364-8535</issn>
      <issn pub-type="epub">1466-609X</issn>
      <publisher>
        <publisher-name>BioMed Central</publisher-name>
        <publisher-loc>London</publisher-loc>
      </publisher>
    </journal-meta>
    ...
```

Topics

The topics for the track consist of synthetic patient cases consist of the disease, genetic variants, and the proposed treatment.

| | Patient 1 | Patient 2 |
|-------------------|--------------|--------------|
| Disease: | melanoma | melanoma |
| Variant: | BRAF (V600E) | BRAF (V600E) |
| Treatment: | Dabrafenib | Cobimetinib |

Topics in XML format: [topic2020.xml](#)

Relevance Judgments

- Binary (*relevant* vs. *non-relevant*) in the simplest case
 - ▶ More nuanced relevance levels also used (e.g., 0-3 scale)
- Any Issues?
 - ▶ Human judges often disagree
 - ▶ We expect to pay human experts (doctors, medical coders, etc.)

```
1 0 1065003 1
1 0 1065013 1
1 0 1065027 1
1 0 1065055 0
1 0 1065094 2
1 0 107740 0
1 0 1079876 0
1 0 1160567 1
1 0 1160569 1
1 0 117132 0
1 0 1175863 1
1 0 1175871 0
1 0 1175911 0
1 0 1180426 0
```


Pooling technique and Why?

- In most collections, it is not feasible to assess the relevance of each document for each query;
 - ▶ For example, 10,000 predicted documents for 50 topics from 100 participating systems. Assuming that judging each document takes 5 mins, then it will take up to 475 years to evaluate!!
- Hence, pooling technique is used on a large scale IR evaluation tasks.

Typical Pooling Sequence

- 1 The documents and queries are created.
- 2 Multiple IR systems are run on the queries.
- 3 Each system returns top-ranking m documents, which are collected into a pool.
- 4 The resulting pool of documents is assessed in random order, typically by multiple judges.
- 5 When judges disagree, they meet and discuss the document until they reach consensus.

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Issues of Static Test Collections

- IR systems are becoming increasingly **contextual and personal**;
- Users and their information needs are too **diverse and dynamic** to be adequately captured in static test collections;
- No longer can users or experts be asked to provide **objective assessments**.

Online evaluation for IR addresses the challenges that require assessment of systems in terms of their utility for the user.

Online Evaluation

- **Online evaluation** is the evaluation of a fully functioning system based on implicit measurement of real users' experiences of the system in a natural usage environment.
- **Implicit measurement**, include any measurements that can be derived from observable user activity that is part of users' natural or normal interaction with the system.
- Distinction between implicit and explicit measurements is that **implicit measurements** are a by-product of users' natural interaction, while **explicit ones** are specifically collected for feedback purposes.

Offline vs. Online Evaluation

- **Offline Evaluation:**

- ▶ Direct comparison of one engine to another
- ▶ Simple and easy to replicate and reproduce

- **Online Evaluation:**

- ▶ Accounts for the actual user behavior during interactive sessions
- ▶ Complex and costly and it is not reproducible

- **Offline Estimation:**

- ▶ The estimation of online evaluation based on past observations of users' behavior

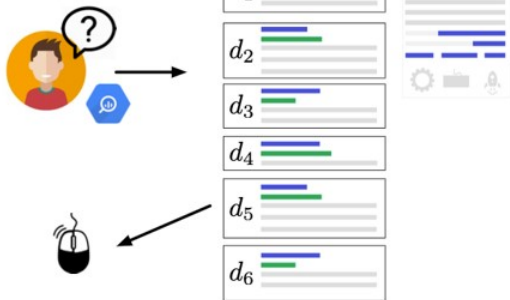
Click Log Data

Query logs have proven to be a valuable and informative source of implicit user feedback:

- they can be easily collected by search engines;
- they are available in real time;
- they represent personalized user preferences.

Terminology

The user starts a **session** by issuing a query to the IR System



Terminology (Cont.)

- **Session**: series of interactions by the user toward addressing a single information need;
- Session, task, and goal are often used as synonymous, depending on whether a study was based on logs (where extracting session is easier than identifying tasks) or in a laboratory (where study participants complete one task or search goal at a time).

Terminology (Cont.)

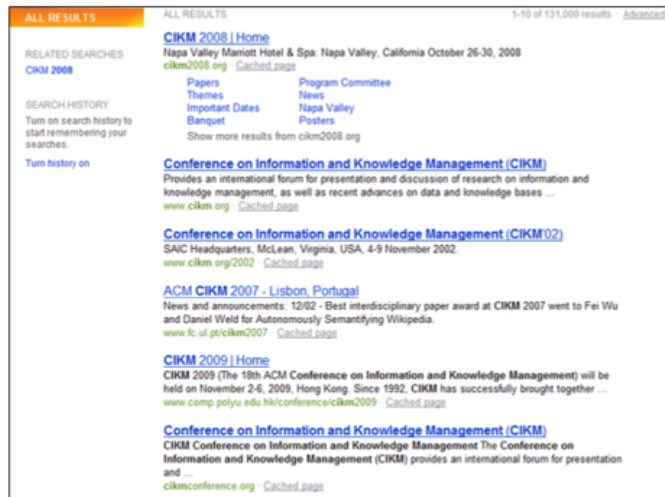


Terminology (Cont.)

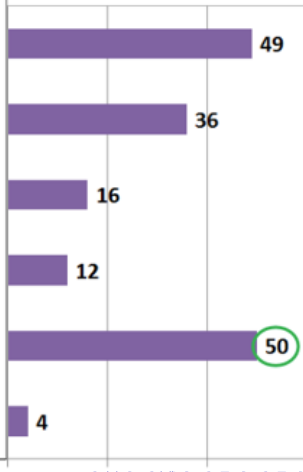


User Behavior

Search results for “CIKM” (in 2009!)



of clicks received



User Behavior (Cont.)

Adapt ranking to user clicks?

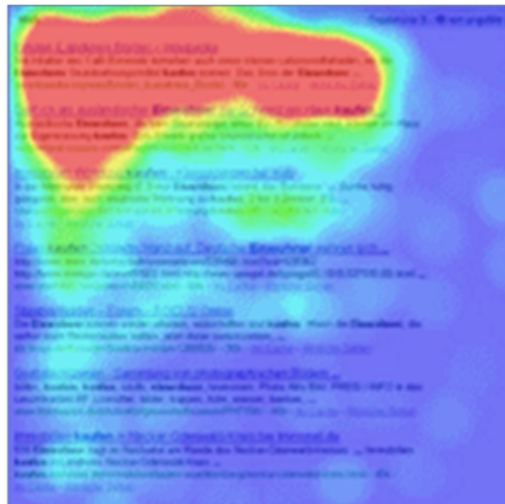


User Behavior (Cont.)

Tools needed for non-trivial cases

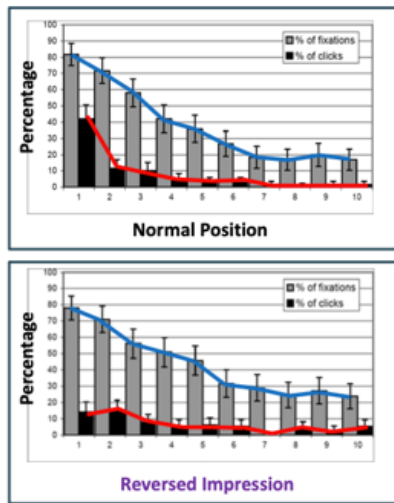


Eye-Tracking User Study



Strong position bias exists, so absolute click rates are unreliable.

Click Position-Bias



- Higher positions receive more user attention (eye fixation) and clicks than lower positions
- This is true even in the extreme setting where the order of positions is reversed
- “Clicks are informative but biased”

¹[Joachims+07]

Relative vs. Absolute Ratings

The screenshot shows a search results page for 'CIKM 2008'. The page has a header with 'ALL RESULTS' and '1-10 of 131,000 results'. On the left, there are sections for 'RELATED SEARCHES' (CIKM 2008), 'SEARCH HISTORY', and 'Turn on search history'. The main content area lists several search results, each with a title, description, and URL. A blue zigzag arrow starts at the top right and points to the following results in order: 'CIKM 2008 | Home', 'Conference on Information and Knowledge Management (CIKM)', 'Conference on Information and Knowledge Management (CIKM02)', 'ACM CIKM 2007 - Lisbon, Portugal', and 'CIKM 2009 | Home'.

ALL RESULTS 1-10 of 131,000 results - advanced

RELATED SEARCHES
CIKM 2008

SEARCH HISTORY
Turn on search history to start remembering your searches.
Turn history on

[CIKM 2008 | Home](#)
Napa Valley Marriott Hotel & Spa: Napa Valley, California October 26-30, 2008
[cikm2008.org](#) - [Cached page](#)

Papers Themes Program Committee
Important Dates News
Banquet Napa Valley
Posters
Show more results from cikm2008.org

[Conference on Information and Knowledge Management \(CIKM\)](#)
Provides an international forum for presentation and discussion of research on information and knowledge management, as well as recent advances on data and knowledge bases ...
[www.cikm.org](#) - [Cached page](#)

[Conference on Information and Knowledge Management \(CIKM02\)](#)
SAIC Headquarters, McLean, Virginia, USA, 4-9 November 2002.
[www.cikm.org/2002](#) - [Cached page](#)

[ACM CIKM 2007 - Lisbon, Portugal](#)
News and announcements: 12/02 - Best interdisciplinary paper award at CIKM 2007 went to Fei Wu and Daniel Weld for Autonomously Semantifying Wikipedia.
[www.fc.ul.pt/cikm2007](#) - [Cached page](#)

[CIKM 2009 | Home](#)
CIKM 2009 (The 18th ACM Conference on Information and Knowledge Management) will be held on November 2-6, 2009, Hong Kong. Since 1992, CIKM has successfully brought together ...
[www.comp.polyu.edu.hk/conference/cikm2009](#) - [Cached page](#)

[Conference on Information and Knowledge Management \(CIKM\)](#)
CIKM Conference on Information and Knowledge Management The Conference on Information and Knowledge Management (CIKM) provides an international forum for presentation and ...
[cikmconference.org](#) - [Cached page](#)

User's click
sequence

- Hard to conclude Result1 > Result3

Comparing two rankings via clicks

Query: [support vector machines]

Ranking A

| |
|-----------------|
| Kernel machines |
| SVM-light |
| Lucent SVM demo |
| Royal Holl. SVM |
| SVM software |
| SVM tutorial |

Ranking B

| |
|-----------------|
| Kernel machines |
| SVMs |
| Intro to SVMs |
| Archives of SVM |
| SVM-light |
| SVM software |

Interleaving two rankings

This interleaving starts with the ranking B.

| |
|-----------------|
| Kernel machines |
| Kernel machines |
| SVMs |
| SVM-light |
| Intro to SVMs |
| Lucent SVM demo |
| Archives of SVM |
| Royal Holl. SVM |
| SVM-light |

...

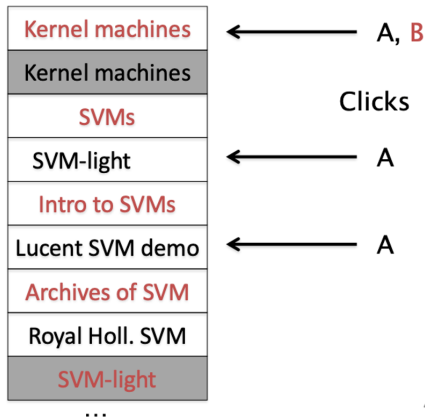
Remove duplicate results

| |
|-----------------|
| Kernel machines |
| Kernel machines |
| SVMs |
| SVM-light |
| Intro to SVMs |
| Lucent SVM demo |
| Archives of SVM |
| Royal Holl. SVM |
| SVM-light |

...

Count User Clicks

Ranking A: 3
Ranking B: 1



Interleaved Rankings

- Present interleaved ranking to users
- Start randomly with ranking A or ranking B to even out presentation bias
- Count clicks on results from A versus results from B
- Better ranking will (on average) get more clicks

A/B testing at web search engines

- Purpose: Test a single innovation
- Prerequisite: You have a large search engine up and running.
- Have most users use old system
- Divert a small proportion of traffic (e.g., 0.1%) to an experiment to evaluate an innovation
 - ▶ Interleaved experiment
 - ▶ Full page experiment

Question-answering / Knowledge Panel

What happens to clicks?

The screenshot shows a Google search interface in a Chrome browser. The search query is "mount everest height". The results page features a knowledge panel on the left and a detailed information box on the right.

Knowledge Panel (Left):

- 29,029' (8,848 m)**
Mount Everest, Elevation
- Mount Everest - Wikipedia, the free encyclopedia**
https://en.wikipedia.org/wiki/Mount_Everest
- By the same measure of base to summit, **Mount McKinley**, in Alaska, is also taller than **Everest**. Despite its **height** above sea level of only 6,193.6 m (20,320 ft), ...
- [List of deaths on eight - List of people who died ... - Timeline of climbing Mount](#)
- Facts About Mt. Everest - Scholastic**
[teacher.scholastic.com/activities/hillary/archive/evfacts.htm](https://www.scholastic.com/activities/hillary/archive/evfacts.htm)
- Number of people to successfully climb **Mt. Everest**: 660. Number of

Information Box (Right):

- Mount Everest**
Mountain
- Mount Everest is the Earth's highest mountain, with a peak at 8,848 metres above sea level and the 5th tallest mountain measured from the centre of the Earth. It is located in the Mahalangur section of the Himalayas.
Wikipedia
- Elevation:** 29,029' (8,848 m)
- First ascent:** May 29, 1953
- Base:** 29,029' (8,848 m)

Map: A map showing the location of Mount Everest in the Himalayas, with labels for "Chang Ngar" and "Mount Everest".

User Behavior

- User behavior is an intriguing source of relevance data
 - ▶ Users make (somewhat) informed choices when they interact with search engines
 - ▶ Potentially a lot of data available in search logs
- But there are significant caveats
 - ▶ User behavior data can be very noisy
 - ▶ Interpreting user behavior can be tricky
 - ▶ Spam can be a significant problem
 - ▶ Not all queries will have user behavior

Incorporating user behavior into ranking algorithms

- Incorporate user behavior features into a ranking function
 - ▶ BM25F, a BM25 extension version for weighting terms presented in multiple fields (e.g., user behavior features)
- Incorporate user behavior features into learned ranking function
- Either of these ways of incorporating user behavior signals improve ranking

Summary

- Question?