Introduction to

Information Retrieval

CS276
Information Retrieval and Web Search

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Evaluation

Situation

- Thanks to your stellar performance in CS276, you quickly rise to VP of Search at internet retail giant nozama.com. Your boss brings in her nephew Sergey, who claims to have built a better search engine for nozama. Do you
  - Laugh derisively and send him to rival Tramlaw Labs?
  - Counsel Sergey to go to Stanford and take CS276?
  - Try a few queries on his engine and say "Not bad"?
  - … ?

What could you ask Sergey?

- How fast does it index?
  - Number of documents/hour
  - Incremental indexing – nozama adds 10K products/day
- How fast does it search?
  - Latency and CPU needs for nozama's 5 million products
- Does it recommend related products?
- This is all good, but it says nothing about the *quality* of Sergey's search
  - You want nozama's users to be happy with the search experience

How do you tell if users are happy?

- Search returns products relevant to users
  - How do you assess this at scale?
- Search results get clicked a lot
  - Misleading titles/summaries can cause users to click
- Users buy after using the search engine
  - Or, users spend a lot of $ after using the search engine
- Repeat visitors/buyers
  - Do users leave soon after searching?
  - Do they come back within a week/month/… ?

Happiness: elusive to measure

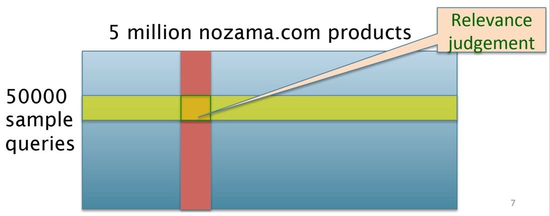
- Most common proxy: *relevance* of search results
  - But how do you measure relevance?
- Pioneered by Cyril Cleverdon in the Cranfield Experiments

Measuring relevance

- Three elements:
  1. A benchmark document collection
  2. A benchmark suite of queries
  3. An assessment of either Relevant or Nonrelevant for each query and each document

So you want to measure the quality of a new search algorithm

- Benchmark documents – nozama's products
- Benchmark query suite – more on this
- Judgments of document relevance for each query



Relevance judgments

- Binary (relevant vs. non-relevant) in the simplest case, more nuanced (0, 1, 2, 3 …) in others
- What are some issues already?
- 5 million times 50K takes us into the range of a quarter trillion judgments
  - If each judgment took a human 2.5 seconds, we'd still need 10^{11} seconds, or nearly $300 million if you pay people $10 per hour to assess
  - 10K new products per day

Crowd source relevance judgments?

- Present query-document pairs to low-cost labor on online crowd-sourcing platforms
  - Hope that this is cheaper than hiring qualified assessors
- Lots of literature on using crowd-sourcing for such tasks
- Main takeaway – you get some signal, but the variance in the resulting judgments is very high

Evaluating an IR system

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

What else?

- Still need test queries
  - Must be germane to docs available
  - Must be representative of actual user needs
  - Random query terms from the documents generally not a good idea
  - Sample from query logs if available
- Classically (non-Web)
  - Low query rates – not enough query logs
  - Experts hand-craft "user needs"

Some public test Collections

TABLE 4.3 Common Test Corpora

Collection	*NDocs*	*NQrys*	*Size (MB)*	*Term/Doc*	*Q-D RelAss*
ADI	82	35			
AIT	2109	14	2	400	>10,000
CACM	3204	64	2	24.5	
CISI	1460	112	2	46.5	
Cranfield	1400	225	2	53.1	
LISA	5872	35	3		
Medline	1033	30	1		
NPL	11,429	93	3		
OSHMED	34,8566	106	400	250	16,140
Reuters	21,578	672	28	131	
TREC	740,000	200	2000	89-3543	» 100,000

Typical TREC

Now we have the basics of a benchmark

- Let's review some evaluation measures
  - *Precision*
  - *Recall*
  - NDCG
  - …

Unranked retrieval evaluation: Precision and Recall – recap from IIR 8/video

- **Binary assessments**

Precision: fraction of retrieved docs that are relevant = P(relevant|retrieved)

Recall: fraction of relevant docs that are retrieved = P(retrieved|relevant)

	Relevant	Nonrelevant
Retrieved	tp	fp
Not Retrieved	fn	tn

- Precision P = tp/(tp + fp)
- Recall R = tp/(tp + fn)

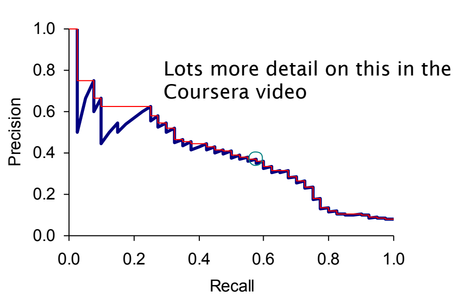
Rank-Based Measures

- Binary relevance
  - Precision@K (P@K)
  - Mean Average Precision (MAP)
  - Mean Reciprocal Rank (MRR)
- Multiple levels of relevance
  - Normalized Discounted Cumulative Gain (NDCG)

Precision@K

- Set a rank threshold K
- Compute % relevant in top K
- Ignores documents ranked lower than K
- Ex:
  - Prec@3 of 2/3
  - Prec@4 of 2/4
  - Prec@5 of 3/5
- In similar fashion we have Recall@K

A precision-recall curve



Mean Average Precision

- Consider rank position of each ***relevant*** doc
  - $K_1, K_2, \ldots K_R$
- Compute Precision@K for each $K_1, K_2, \ldots K_R$
- Average precision = average of P@K
- Ex: has AvgPrec of $\frac{1}{3}\cdot\left(\frac{1}{1}+\frac{2}{3}+\frac{3}{5}\right)\approx 0.76$
- MAP is Average Precision across multiple queries/ rankings

Average Precision

■ ■ ■ ■ ■ ■ = the relevant documents

Ranking #1

	■	□	■	■	■	■	□	□	□	■
Recall	0.17	0.17	0.33	0.5	0.67	0.83	0.83	0.83	0.83	1.0
Precision	1.0	0.5	0.67	0.75	0.8	0.83	0.71	0.63	0.56	0.6

Ranking #2

	□	■	□	□	■	■	■	□	■	■
Recall	0.0	0.17	0.17	0.17	0.33	0.5	0.67	0.67	0.83	1.0
Precision	0.0	0.5	0.33	0.25	0.4	0.5	0.57	0.5	0.56	0.6

$$\text{Ranking \#1: } (1.0 + 0.67 + 0.75 + 0.8 + 0.83 + 0.6)/6 = 0.78$$

$$\text{Ranking \#2: } (0.5 + 0.4 + 0.5 + 0.57 + 0.56 + 0.6)/6 = 0.52$$

MAP

■ ■ ■ ■ ■ = relevant documents for query 1

Ranking #1

	■	□	■	□	□	■	□	□	■	■
Recall	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.6	0.8	1.0
Precision	1.0	0.5	0.67	0.5	0.4	0.5	0.43	0.38	0.44	0.5

■ ■ ■ = relevant documents for query 2

Ranking #2

	□	■	□	□	■	□	■	□	□	□
Recall	0.0	0.33	0.33	0.33	0.67	0.67	1.0	1.0	1.0	1.0
Precision	0.0	0.5	0.33	0.25	0.4	0.33	0.43	0.38	0.33	0.3

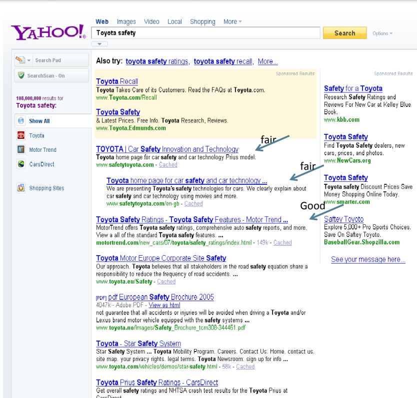
$$\textit{average precision query 1} = (1.0 + 0.67 + 0.5 + 0.44 + 0.5)/5 = 0.62$$
$$\textit{average precision query 2} = (0.5 + 0.4 + 0.43)/3 = 0.44$$

$$\textit{mean average precision} = (0.62 + 0.44)/2 = 0.53$$

Mean average precision

- 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

BEYOND BINARY RELEVANCE



Discounted Cumulative Gain

- Popular measure for evaluating web search and related tasks
- Two assumptions:
  - Highly relevant documents are more useful than marginally relevant documents
  - the lower the ranked position of a relevant document, the less useful it is for the user, since it is less likely to be examined

Discounted Cumulative Gain

- Uses *graded relevance* as a measure of usefulness, or *gain,* from examining a document
- 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)*
  - With base 2, the discount at rank 4 is 1/2, and at rank 8 it is 1/3

Summarize a Ranking: DCG

- What if relevance judgments are in a scale of [0,r]? r>2
- Cumulative Gain (CG) at rank n
  - Let the ratings of the n documents be r_1, r_2, …r_n (in ranked order)
  - CG = $r_1+r_2+\ldots r_n$
- Discounted Cumulative Gain (DCG) at rank n
  - DCG = $r_1 + r_2/\log_2 2 + r_3/\log_2 3 + \ldots r_n/\log_2 n$
    - We may use any base for the logarithm

Discounted Cumulative Gain

- *DCG* is the total gain accumulated at a particular rank *p*:

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

- Alternative formulation:

$$DCG_p = \sum_{i=1}^{p} \frac{2^{rel_i}-1}{log(1+i)}$$

  - used by some web search companies
  - emphasis on retrieving highly relevant documents

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
- DCG:
  3, 5, 6.89, 6.89, 6.89, 7.28, 7.99, 8.66, 9.61, 9.61

Summarize a Ranking: NDCG

- Normalized Discounted Cumulative Gain (NDCG) at rank *n*
  - Normalize 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 useful for contrasting queries with varying numbers of relevant results
- NDCG is now quite popular in evaluating Web search

NDCG - Example

4 documents: d_1, d_2, d_3, d_4

i	Ground Truth		Ranking Function$_1$		Ranking Function$_2$	
	Document Order	r_i	Document Order	r_i	Document Order	r_i
1	d4	2	d3	2	d3	2
2	d3	2	d4	2	d2	1
3	d2	1	d2	1	d4	2
4	d1	0	d1	0	d1	0
	$NDCG_{GT}$=1.00		$NDCG_{RF1}$=1.00		$NDCG_{RF2}$=0.9203	

$$DCG_{GT} = 2 + \left(\frac{2}{\log_2 2} + \frac{1}{\log_2 3} + \frac{0}{\log_2 4} \right) = 4.6309$$

$$DCG_{RF1} = 2 + \left(\frac{2}{\log_2 2} + \frac{1}{\log_2 3} + \frac{0}{\log_2 4} \right) = 4.6309$$

$$DCG_{RF2} = 2 + \left(\frac{1}{\log_2 2} + \frac{2}{\log_2 3} + \frac{0}{\log_2 4} \right) = 4.2619$$

$$MaxDCG = DCG_{GT} = 4.6309$$

What if the results are not in a list?

- Suppose there's only one Relevant Document
- Scenarios:
  - known-item search
  - navigational queries
  - looking for a fact
- Search duration ~ Rank of the answer
  - measures a user's effort

Mean Reciprocal Rank

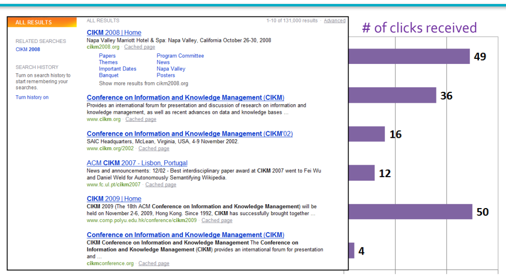
- Consider rank position, K, of first relevant doc
  - Could be – only clicked doc
- Reciprocal Rank score = $\frac{1}{K}$
- MRR is the mean RR across multiple queries

Human judgments are

- Expensive
- Inconsistent
  - Between raters
  - Over time
- Decay in value as documents/query mix evolves
- Not always representative of "real users"
  - Rating vis-à-vis query, vs underlying need
- So – what alternatives do we have?

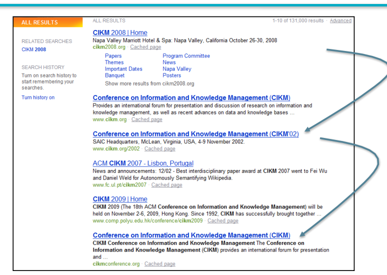
USING USER CLICKS

What do clicks tell us?



Strong position bias, so absolute click rates unreliable

Relative vs absolute ratings



User's click sequence

Hard to conclude <u>Result1 > Result3</u>
Probably can conclude <u>Result3 > Result2</u>

Pairwise relative ratings

- Pairs of the form: DocA better than DocB for a query
  - Doesn't mean that DocA relevant to query
- Now, rather than assess a rank-ordering wrt per-doc relevance assessments
- Assess in terms of conformance with historical pairwise preferences recorded from user 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., 1%) to an experiment to evaluate an innovation
  - Full page experiment
  - Interleaved experiment

Comparing two rankings via clicks (Joachims 2002)

Query: [support vector machines]

Ranking A	Ranking B
Kernel machines	Kernel machines
SVM-light	SVMs
Lucent SVM demo	Intro to SVMs
Royal Holl. SVM	Archives of SVM
SVM software	SVM-light
SVM tutorial	SVM software

Interleave the two rankings

This interleaving starts with 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

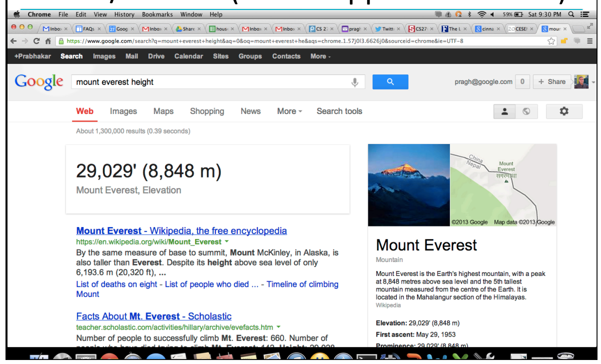
	Clicks
Kernel machines	A, B
Kernel machines	
SVMs	
SVM-light	A
Intro to SVMs	
Lucent SVM demo	A
Archives of SVM	
Royal Holl. SVM	
SVM-light	

…

Interleaved ranking

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

Facts/entities (what happens to clicks?)



Comparing two rankings to a baseline ranking

- Given a set of pairwise preferences *P*
- We want to measure two rankings *A* and *B*
- Define a proximity measure between *A* and *P*
  - And likewise, between *B* and *P*
- Want to declare the ranking with better proximity to be the winner
- Proximity measure should reward agreements with *P* and penalize disagreements

Kendall tau distance

- Let X be the number of agreements between a ranking (say *A*) and *P*
- Let Y be the number of disagreements
- Then the Kendall tau distance between *A* and *P* is (X-Y)/(X+Y)
- Say P = {(1,2), (1,3), (1,4), (2,3), (2,4), (3,4))} and A=(1,3,2,4)
- Then X=5, Y=1 …
- (What are the minimum and maximum possible values of the Kendall tau distance?)

Recap

- Benchmarks consist of
  - Document collection
  - Query set
  - Assessment methodology
- Assessment methodology can use raters, user clicks, or a combination
  - These get quantized into a *goodness measure* – Precision/NDCG etc.
  - Different engines/algorithms compared on a benchmark together with a goodness measure