Introduction to

Information Retrieval

Lecture 7

Evaluation

How do you evaluate a search engine / algorithm [say for e-commerce]

- How fast does it index?
  - Number of documents/hour
  - Incremental indexing – site adds 10K products/day
- How fast does it search?
  - Latency and CPU needs for site's 5 million products
- Does it recommend related products?
- This is all good, but it says nothing about the *quality* of search
  - You want the 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 <u>Relevant</u> or <u>Nonrelevant</u> for each query and each document

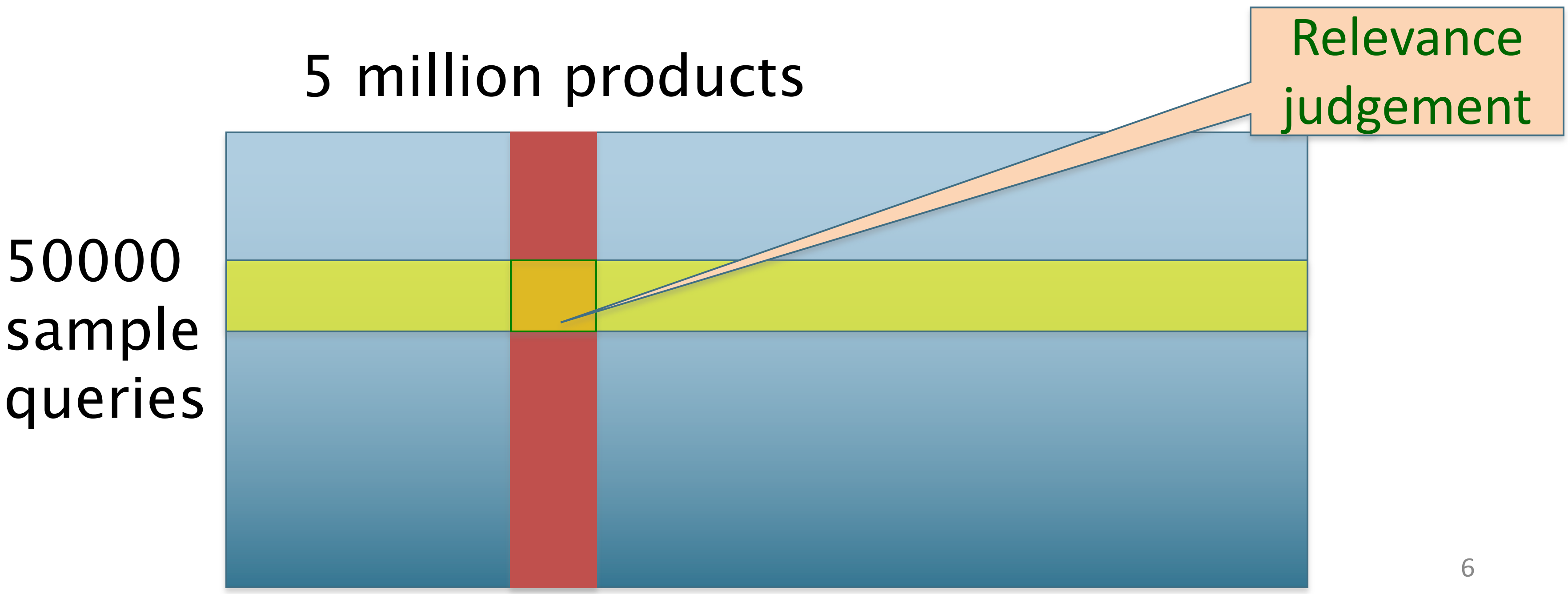
q_1 d_1 1 $q_2 \to$ 0

d_2 0 0

d_3 1 1

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

- Benchmark documents – the 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

What else?

- Still need test queries
  - Must be appropriate to docs in corpus
  - 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

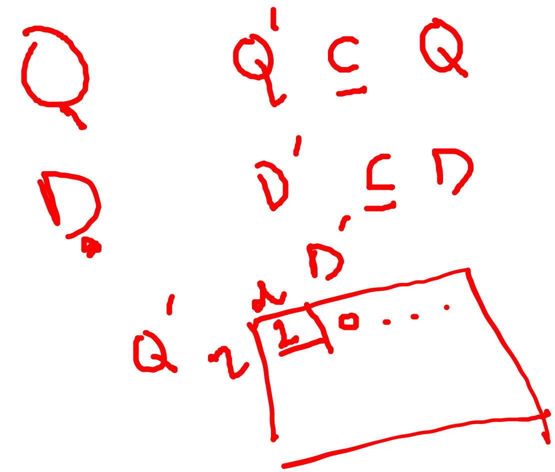
Typical TREC

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

Now we have the basics of a benchmark

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



Unranked retrieval evaluation: Precision and Recall

- **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)

e

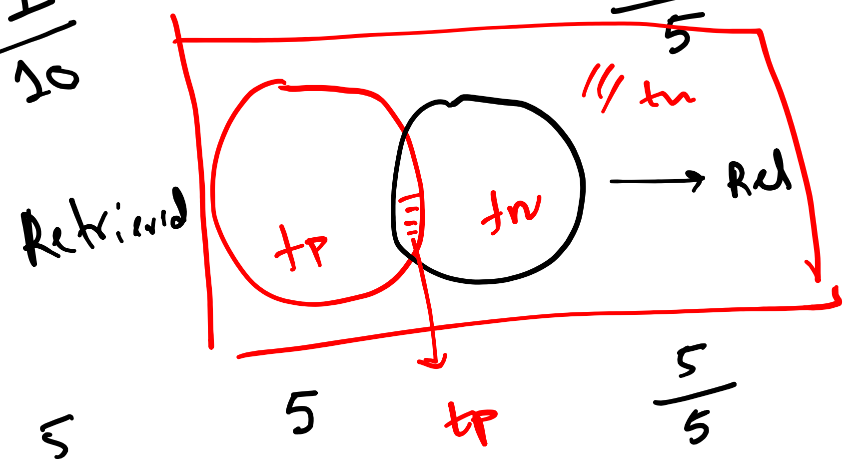
10 doc – 1

5 rel

$D = \cancel{100/200}$ 1K

$\frac{1}{10}$

$\frac{1}{5}$



correct among all

$$A = \frac{tp + tn}{tp + tn + fn + fp}$$

$\frac{5}{5}$

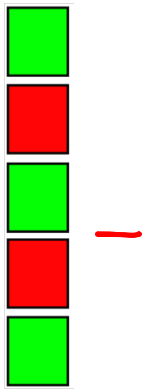
$\frac{5}{10}$

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)

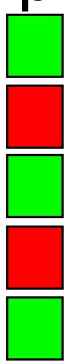
Precision@K

- Set a rank threshold K
- Compute % relevant in top K
- Ignores documents ranked lower than K
- Ex:
  - Prec@3 of ?
  - Prec@4 of ?
  - Prec@5 of ?

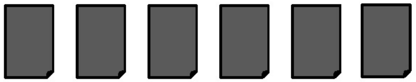


- In similar fashion we have Recall@K

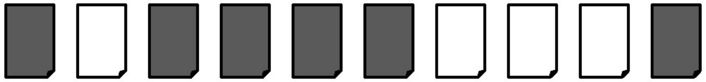
Mean Average Precision

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

Average Precision

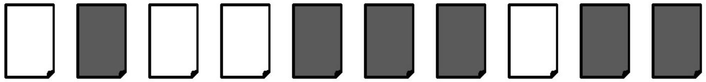
 = the relevant documents

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

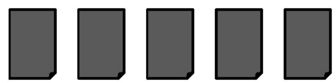
$$\text{Ranking \#1: } (1.0 + 0.67 + 0.75 + 0.8 + 0.83 + 0.6)/6 = 0.78$$

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

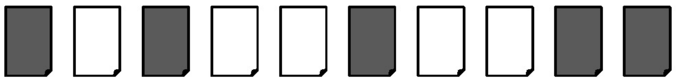
Mean average precision

- MAP is Average Precision across multiple queries/rankings
- MAP is macro-averaging: each query counts equally
- Now perhaps most commonly used measure in research papers

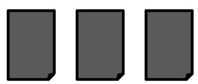
MAP


= relevant documents for query 1

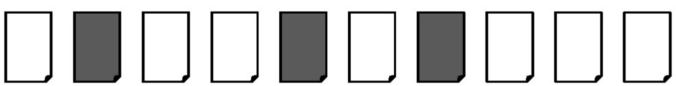
Ranking #1



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

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

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

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

d_m

1- d_1
2- d_2
3- d_m

d_m ✓
d_2
d_1

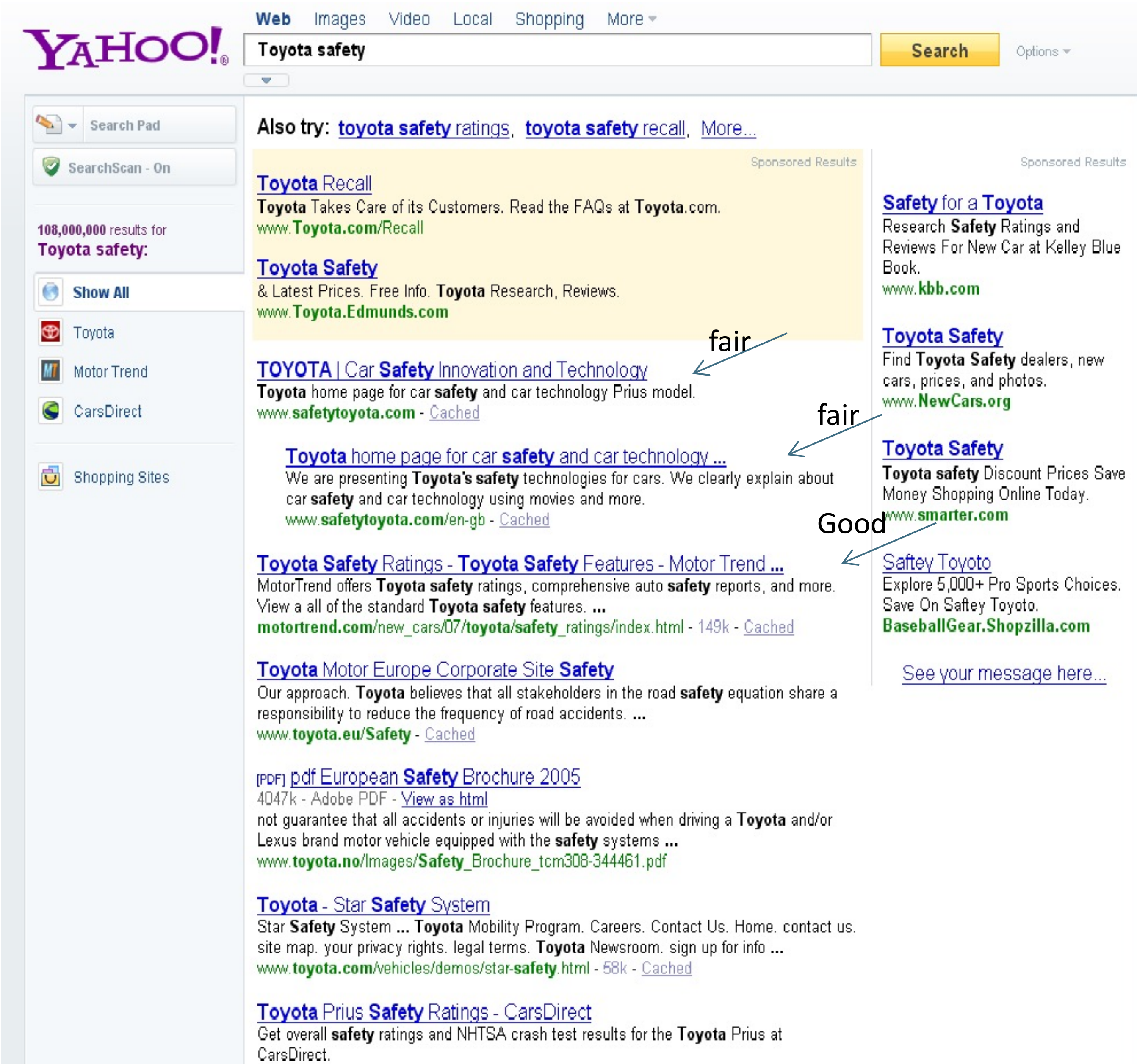
Mean Reciprocal Rank

- 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

BEYOND BINARY RELEVANCE


YAHOO!
Web Images Video Local Shopping More
Toyota safety
Search
Options
Search Pad
SearchScan - On
108,000,000 results for
Toyota safety:
Show All
Toyota
Motor Trend
CarsDirect
Shopping Sites
Also try: toyota safety ratings, toyota safety recall, More...
Sponsored Results
Toyota Recall
Toyota Takes Care of its Customers. Read the FAQs at Toyota.com.
www.Toyota.com/Recall
Toyota Safety
& Latest Prices. Free Info. Toyota Research, Reviews.
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Toyota home page for car safety and car technology ...
We are presenting Toyota's safety technologies for cars. We clearly explain about car safety and car technology using movies and more.
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MotorTrend offers Toyota safety ratings, comprehensive auto safety reports, and more. View a all of the standard Toyota safety features. ...
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Good
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Our approach. Toyota believes that all stakeholders in the road safety equation share a responsibility to reduce the frequency of road accidents. ...
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not guarantee that all accidents or injuries will be avoided when driving a Toyota and/or Lexus brand motor vehicle equipped with the safety systems ...
www.toyota.no/Images/Safety_Brochure_tcm308-344461.pdf
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Star Safety System ... Toyota Mobility Program. Careers. Contact Us. Home. contact us. site map. your privacy rights. legal terms. Toyota Newsroom. sign up for info ...
www.toyota.com/vehicles/demos/star-safety.html - 58k - Cached
Toyota Prius Safety Ratings - CarsDirect
Get overall safety ratings and NHTSA crash test results for the Toyota Prius at CarsDirect.
Sponsored Results
Safety for a Toyota
Research Safety Ratings and Reviews For New Car at Kelley Blue Book.
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Find Toyota Safety dealers, new cars, prices, and photos.
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Explore 5,000+ Pro Sports Choices. Save On Saftey Toyota.
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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
  - Intuition: if a good document is retrieved at rank 4, system gets only half the credit that it would have got if the doc were to be retrieved at rank 1

1 2 3 4 Ranks

gain

d_{i_1} d_{i_2} d_{i_3} d_{i_4}

3 0 0 0

0

Disc gain

d_{i_1} d_{i_2} d_{i_3} d_{i_4}

→ 3 0 0 0 3

d_{i_2} d_{i_3} d_{i_1} d_{i_4}

0 0 3 0 $3/\log_2(3)$

Summarize a Ranking: DCG

- What if relevance judgments are in a scale of [0,k]? k>=2
- Let the ratings of the n documents be r_1, r_2, …r_n (in ranked order)
- Cumulative Gain (CG) at rank n
  - CG = $r_1+r_2+\dots r_n$

    3 + 0 + 0 + 0
- Discounted Cumulative Gain (DCG) at rank n
  - DCG = $r_1 + r_2/\log_2 2 + r_3/\log_2 3 + \dots r_n/\log_2 n$
    - We may use any base for the logarithm

→ 3 + 0 + 0 + 0

→ 0 + 0 + 3/log 3 + 0

Discounted Cumulative Gain

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

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

  - 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

- A problem: how to compare DCG for queries having different number of relevant docs?

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 for the same example

- 10 ranked documents judged on 0-3 relevance scale:
  3, 2, 3, 0, 0, 1, 2, 2, 3, 0
- Perfect ranking: 3, 3, 3, 2, 2, 2, 1, 0, 0, 0
- Ideal DCG values:
  - 3, 6, 7.89, 8.89, 9.75, 10.52, 10.88, 10.88, 10.88, 10
- Actual DCG (from two slides back):
  - 3, 5, 6.89, 6.89, 6.89, 7.28, 7.99, 8.66, 9.61, 9.61
- NDCG values (divide actual by ideal):
  - 1, 0.83, 0.87, 0.76, 0.71, 0.69, 0.73, 0.8, 0.88, 0.88
  - NDCG $\leq$ 1 at any rank position

$3/3$ $5/6$ $6.89/7.89$ . . .

NDCG – Another 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	

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

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

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

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