Information Retrieval

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Evaluation

In **ad hoc** document retrieval, the system is given a short query q and the task is to produce the best ranking of documents in a corpus, according to some standard metric such as average precision (AP).

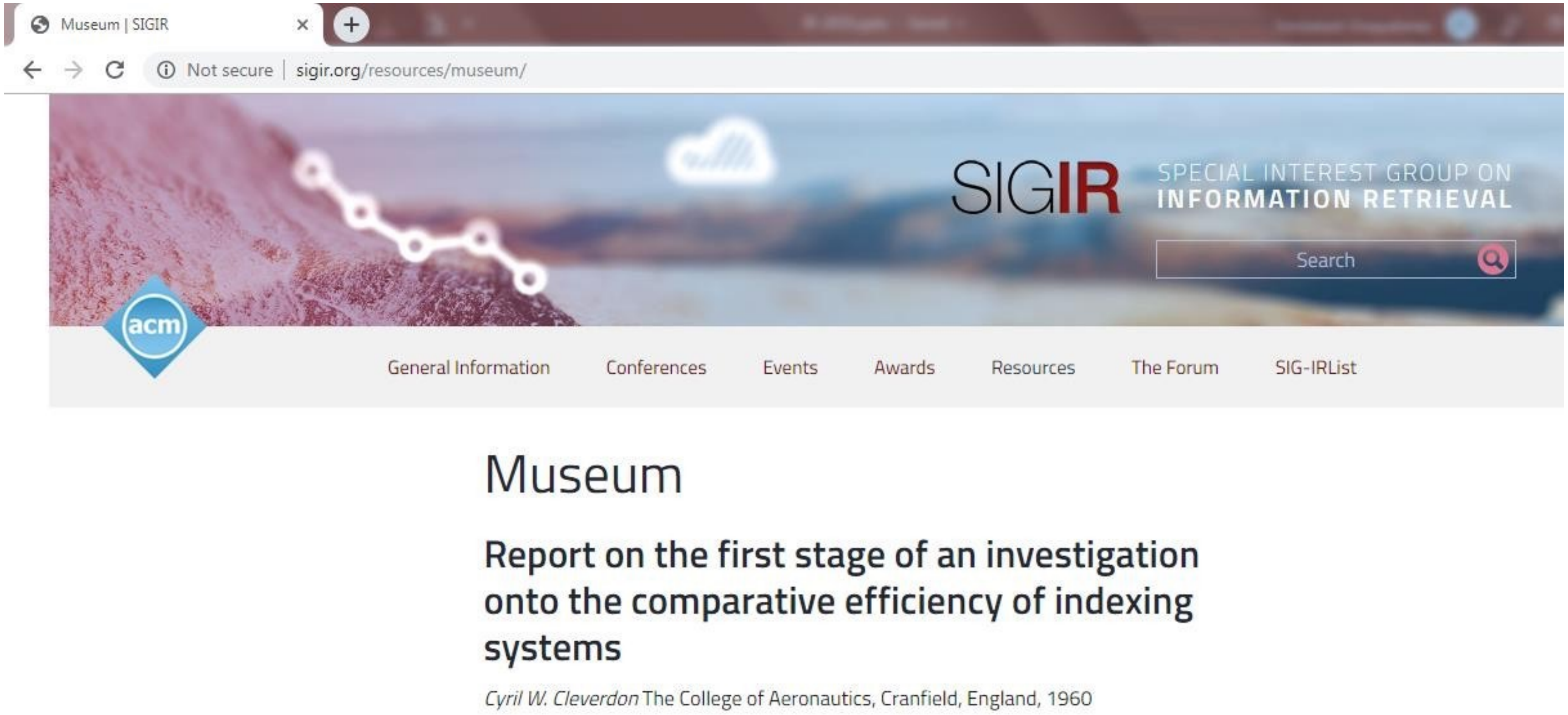
Earlier we had drop-downs for query field. Nowadays, query is a free-text!

Simple Applications of BERT for Ad Hoc Document Retrieval, Yang, Zhang and Lin, University of Waterloo, 2019

Standard Test Collections for Ad Hoc Retrieval

- **Cranfield Collection** [1950]: Contains 1398 abstracts of journal articles, 225 queries, exhaustive judgments for all query-document pairs.
- **Text Retrieval Conference** (TREC) [1992]: 1.89 billion documents, relevance judgments for 450 information needs. Judgments for top-k documents.
- **GOV2**: 25 Million .gov web pages!
- **NTCIR and CLEF**: Cross language information retrieval collection has queries in one language over a collection with multiple languages.
- **Reuters-RCV1, 20 Newsgroups**, …

The SIGIR Museum



Museum

Report on the first stage of an investigation onto the comparative efficiency of indexing systems

Cyril W. Cleverdon The College of Aeronautics, Cranfield, England, 1960

Special Interest Group on Information Retrieval

Evaluation

How to compare Search Engines?
How good is an IR system?

- Various evaluation methods
  - **Precision/Recall**
  - Mean Average Precision
  - Mean Reciprocal Rank
    - If first relevant doc is at kth position, RR = 1/k.
  - NDCG (Non-Boolean Discounted Cumulative Gain)
    - Non-Boolean/Graded relevance scores
    - DCG = $r_1 + r_2/\log_2 2 + r_3/\log_2 3 + \ldots r_n/\log_2 n$

Precision and Recall

$$\text{precision} = \frac{|\{\text{relevant documents}\} \cap \{\text{retrieved documents}\}|}{|\{\text{retrieved documents}\}|}$$

$$\text{recall} = \frac{|\{\text{relevant documents}\} \cap \{\text{retrieved documents}\}|}{|\{\text{relevant documents}\}|}$$

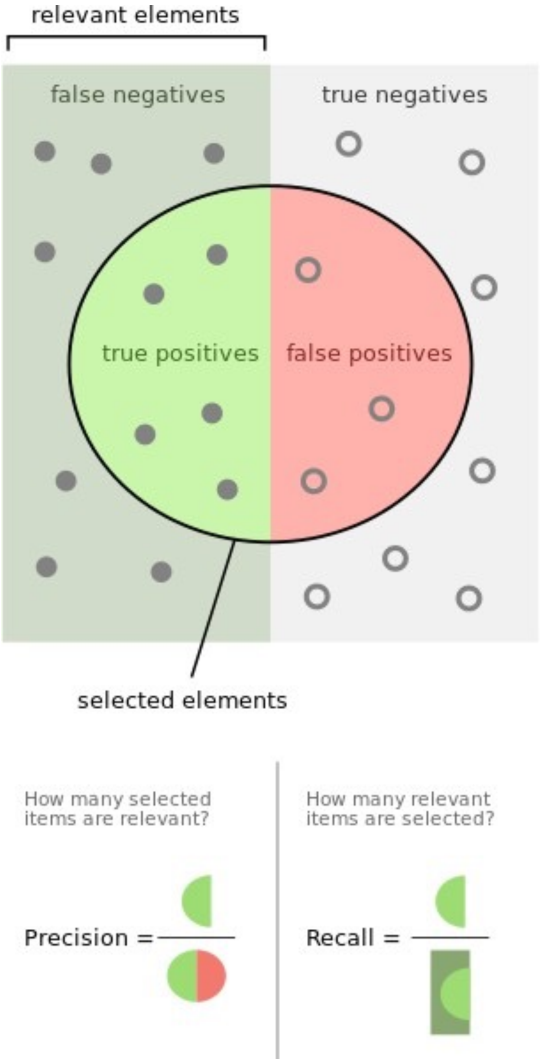


Image Source: Wikipedia

Precision and Recall

- An IR system retrieves the following 20 documents.
- There are 100 relevant documents in our collection.
- Hollow squares represent irrelevant documents.
- Solid squares with ‘R’ are relevant.

	R	R		R			R		
			R	R	R	R			

- What is Precision?
- What is Recall?

Precision and Recall

- An IR system retrieves the following 20 documents.
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	R	R		R			R		
			R	R	R	R			

- What is Precision? Precision = 8/20.
- What is Recall? Recall = 8/100.

Can we do better?
Can we have one number to express quality?

A minor deviation ahead!

F-Measure

- One measure of performance that takes into account both recall and precision.
- Harmonic mean of recall and precision:

$$F = \frac{2PR}{P+R} = \frac{2}{\frac{1}{R}+\frac{1}{P}}$$

Arithmetic Mean

- What is the arithmetic mean of:
  - 1,2,3
  - 1,2,3,4,5
  - 1,2,3,4,5,6,7
- What is the arithmetic mean of:
  - 1 … 99

Arithmetic Mean

- What is the arithmetic mean of:
  - 1,2,3
  - 1,2,3,4,5
  - 1,2,3,4,5,6,7
- What is the arithmetic mean of:
  - 1 … 99

Answer: $\frac{1}{n}\sigma_{n=1}^{99} n = \frac{1}{n} . \frac{n(n+1)}{2} = \frac{99.100}{99.2} = 50$

Arithmetic Mean

- What is the arithmetic mean of:
  - 7,8,9 ?
  - 11,13,15?
- What is the arithmetic mean of:
  - 1, 9, 10
    - 6.7
  - 1, 8, 10
    - 6.3
  - 1, 7, 10
    - 6

Geometric Mean

- What is the geometric mean of 2 and 8 ?
- Answer: $\sqrt{2.8} = \sqrt{16}$ = 4. (Arithmetic Mean is $\frac{2+8}{2}$ = 5.)

$$\left(\prod_{i=1}^{n} x_i\right)^{\frac{1}{n}} = \sqrt[n]{x_1 x_2 \cdots x_n}$$

Geometric Mean

- What is the geometric mean of:
  - 7,8,9 ? AM=8, GM=7.96
  - 11,13,15? AM=13, GM=12.89
- What is the geometric mean of:
  - 1, 9, 10
    - AM=6.7, GM=4.48
  - 1, 8, 10
    - AM=6.3, GM=4.31
  - 1, 7, 10
    - AM=6, GM=4.1

Quiz

Which computer will you prefer?

	Computer A	Computer B	Computer C
Program 1	1	10	20
Program 2	1000	100	20

Time taken by two programs to execute on different computers.

Quiz

Which computer will you prefer?

	Computer A	Computer B	Computer C
Program 1	1	10	20
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Time taken by two programs to execute on different computers.

Quiz

Which computer will you prefer?

	Computer A	Computer B	Computer C
Program 1	1	10	20
Program 2	1000	100	20

	A	B	C
Prg. 1	1	10	20
Prg. 2	1	0.1	0.02
A. Mean	**1**	**5.05**	**10.01**
G. Mean	**1**	**1**	**0.63**

	A	B	C
Prg. 1	0.1	1	2
Prg. 2	10	1	0.2
A. Mean	**5.05**	**1**	**1.1**
G. Mean	**1**	**1**	**0.63**

	A	B	C
Prg. 1	0.05	0.5	1
Prg. 2	50	5	1
A. Mean	**25.03**	**2.75**	**1**
G. Mean	**1.581**	**1.58**	**1**

Geometric Mean gives a consistent ranking
for normalized values.

Harmonic Mean

- What is the harmonic mean of 2 and 8 ?
- Answer: $\frac{2}{\frac{1}{2}+\frac{1}{8}} =$ 3.2

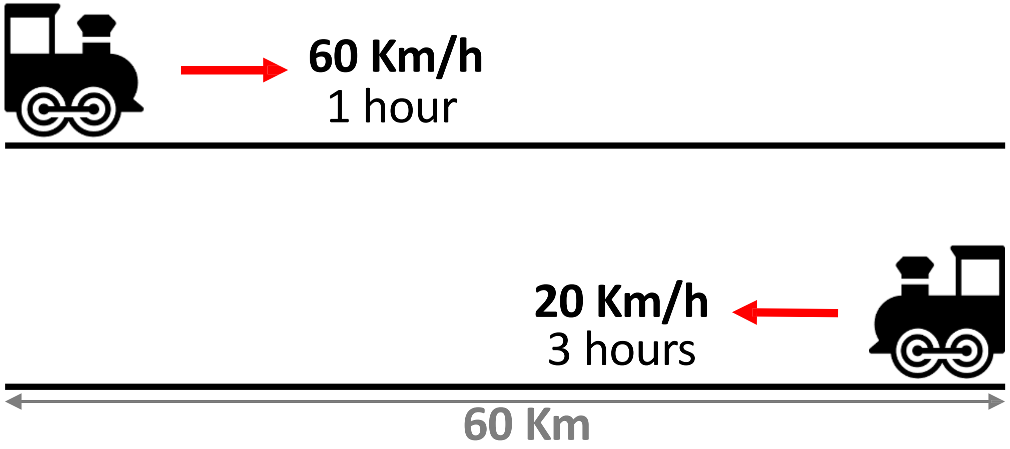
$$H = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \cdots + \frac{1}{x_n}}$$

Harmonic Mean

- What is the harmonic mean of:
    - 7,8,9 ? AM=8, GM=7.96, HM=7.92
    - 11,13,15? AM=13, GM=12.89, HM=12.79
- What is the harmonic mean of:
    - 1, 9, 10
        - AM=6.70, GM=4.48, HM=2.48
    - 1, 8, 10
        - AM=6.30, GM=4.31, HM=2.45
    - 1, 7, 10
        - AM=6.00, GM=4.10, HM=2.41

Quiz

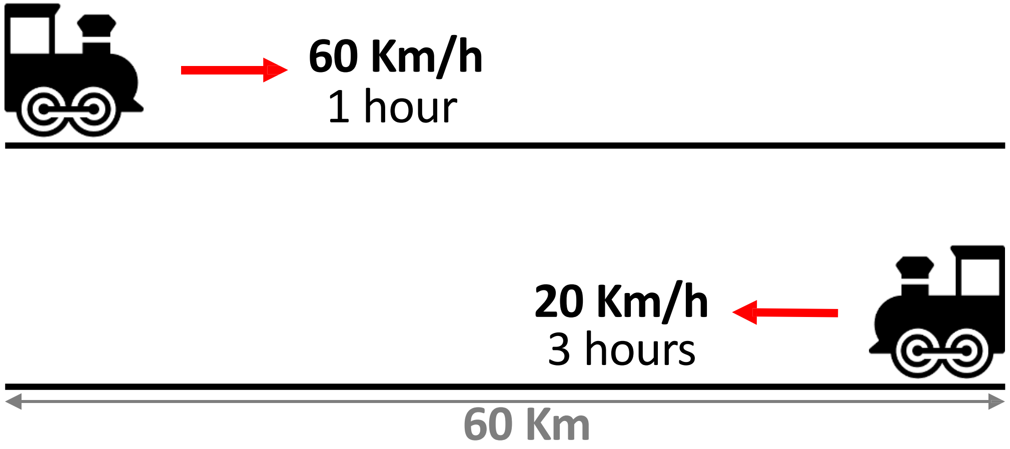
- Can you compute the average speed?



Compute AM, GM and HM of 60 and 20

Quiz

- Can you compute the average speed?



Compute AM, GM and HM of 60 and 20

AM = 40, GM = 34.64, HM = 30

Precision and Recall

Why Harmonic Mean for PR?

Precision and Recall

F1-Score

A Mean for Precision and Recall

$$F_1 = \frac{2PR}{P+R}$$

A more generalized formula:

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

See “The truth of the F-measure” for a detailed discussion.
https://www.toyota-ti.ac.jp/Lab/Denshi/COIN/people/yutaka.sasaki/F-measure-YS-26Oct07.pdf

Precision and Recall

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

Recall: fraction of relevant docs that are retrieved

= P(retrieved & relevant|total relevant)

	Relevant	Nonrelevant
Retrieved	tp	fp
Not Retrieved	fn	tn

- Precision P = tp/(tp + fp)

$$\text{precision} = \frac{|\{\text{relevant documents}\} \cap \{\text{retrieved documents}\}|}{|\{\text{retrieved documents}\}|}$$

- Recall R = tp/(tp + fn)

$$\text{recall} = \frac{|\{\text{relevant documents}\} \cap \{\text{retrieved documents}\}|}{|\{\text{relevant documents}\}|}$$

Quiz

- R refers to Relevant Document
- N refers to Nonrelevant Document.
- Collection has 10,000 documents.
- Assume that there are 8 relevant documents in total in the collection. Calculate Precision and Recall.
- Retrieved Documents:

  RRNNN NNN**R**N **R**NNN**R** NNNN**R**

Precision and Recall

- Precision = 6/20
- Recall = 6/8

Exercise

Suppose, a document is relevant only if both judges agree that it is relevant. Assume (0 = nonrelevant, 1 = relevant). What is the Precision and Recall?

Query = “Taj”

Document ID	Judge 1	Judge 2	Our System
d1 = Bru	0	0	Retrieved
d2 = 3Roses	0	0	No
d3 = Taj	1	1	Retrieved
d4 = Taj Tea	1	1	No
d5 = Taj Mahal	1	0	No

Exercise

Suppose, a document is relevant only if both judges agree that it is relevant. Assume (0 = nonrelevant, 1 = relevant). What is the Precision and Recall?

Query = “Taj”

Document ID	Judge 1	Judge 2	Our System	
d1 = Bru	0	0	Retrieved	False positive
d2 = 3Roses	0	0	No	
d3 = Taj	1	1	Retrieved	True positive
d4 = Taj Tea	1	1	No	
d5 = Taj Mahal	1	0	No	

Exercise

Suppose, a document is relevant only if both judges agree that it is relevant. Assume (0 = nonrelevant, 1 = relevant). What is the Precision and Recall?

Query = “Taj”

Document ID	Judge 1	Judge 2	Our System	
d1 = Bru	0	0	Retrieved	
d2 = 3Roses	0	0	No	True Negative
d3 = Taj	1	1	Retrieved	
d4 = Taj Tea	1	1	No	False Negative
d5 = Taj Mahal	1	0	No	True Negative

Answer

- Precision = 1/2
- Recall = 1/2

Compute Precision and Recall

- Case 1:

1	2	3	4	5	6	7	8	9	10
	R	R		R			R		
			R	R	R	R			

- Case 2:

R	R	R	R	R	R	R	R		

20 documents retrieved. Assume that there are 100 relevant documents.

Compute Precision and Recall

- Case 1: Precision = 8/20, Recall = 8/100

	R	R		R			R		
			R	R	R	R			

- Case 2: Precision = 8/20, Recall = 8/100

R	R	R	R	R	R	R	R		

Which IR system will you prefer?

P, R and F are set based (computed on unordered sets of documents) measures.

Can we do better for ranked documents?

Precision@k

- We cut-off results at k and compute precision.

	R	R		R			R		
			R	R	R	R			

• P@1 = 0				
• P@2 = ½		R		
• P@3 = 2/3		R	R	
• P@4 = 2/4		R	R	

Any Disadvantage?

Precision@k

- We cut-off results at k and compute precision.

	R	R		R			R		
			R	R	R	R			

- P@1 = 0

- P@2 = ½

	R

- P@3 = 2/3

	R	R

- P@4 = 2/4

	R	R	

Disadvantage: If there are only 4 relevant documents in entire collection, and if we retrieve 10 documents, max precision achievable is only 0.4.

Recall@k

- Assume that there are 100 relevant documents.

	R	R		R			R		
			R	R	R	R			

- R@1 = 0

- R@2 = 1/100

	R

- R@3 = 2/100

	R	R

- R@4 = 2/100

	R	R	

Interpolated Precision (R-Precision)

- We cut-off results at kth relevance level.

	R	R		R			R		
			R	R	R	R			

- (Interpolated) P@1 = 0.5

	R

- (Interpolated) P@2 = 2/3

	R	R

Interpolated Average Precision = (0.5 + 0.66) / 2 = 0.58

(if we are only interested in 2 levels of relevance)

What is the Average Precision?

- Case 1:

	R		R		R		R		R

  - Average of Precision at each relevance level.
  - Average Precision = $\frac{\frac{1}{2}+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}+\frac{1}{2}}{5}$

- Case 2:

		R			R			R

- Average Precision = ?

For convenience, we refer to Interpolated Average Precision when we say AP

What is the Average Precision?

- Case 1:

	R		R		R		R		R

  - Average Precision = $\frac{\tfrac{1}{2} + \tfrac{1}{2} + \tfrac{1}{2} + \tfrac{1}{2} + \tfrac{1}{2}}{5}$

- Case 2:

		R			R			R

- Average Precision = 1/3

What is the Average Precision?

- Case 1:

	R		R		R		R		R

  - Average Precision = $\frac{½ + ½ + ½ + ½ + ½}{5}$
  - If there were 10 relevant documents, and we retrieved only five,
    - AP (at relevance level of 10) = $\frac{½ + ½ + ½ + ½ + ½ + 0 + 0 + 0 + 0 + 0}{10}$
- Case 2:

		R			R			R

- What is AP at relevance level of 4? Assume there were 6 relevant documents in our collection.
  - AP = $\frac{1/3 + 1/3 + 1/3 + 0}{4}$

Mean Average Precision

MAP computes Average Precision for all relevance levels for a set of queries.

$$\mathrm{MAP}(Q) = \frac{1}{|Q|}\sum_{j=1}^{|Q|}\frac{1}{m_j}\sum_{k=1}^{m_j}\mathrm{Precision}(R_{jk})$$

Compute MAP

- Query1:

	R		R		R		R		R

Only 5 relevant docs in corpus.

- Query2:

		R			R			R

- Query3:

		R			R			R

Only 3 relevant docs in corpus.

Compute MAP

- Query1:

	R		R		R		R		R

Only 5 relevant docs in corpus.

- Query2:

		R			R			R

- Query3:

		R			R			R

Only 3 relevant docs in corpus.

- Compute MAP.

$$MAP = (1/2 + 1/3 + 1/3)/3$$

?

- Can you compute MAP if you do not know the total number of relevant results for any given query?
  - No! This is the case with web search. Judges may not know how many relevant documents exist.

How to compare two systems, if results are ranked and graded?

and we do not know the total number of relevant documents

Discounted Cumulative Gain

$$DCG_k = \sum_{r=1}^{k} \frac{rel_r}{\log(r+1)}$$

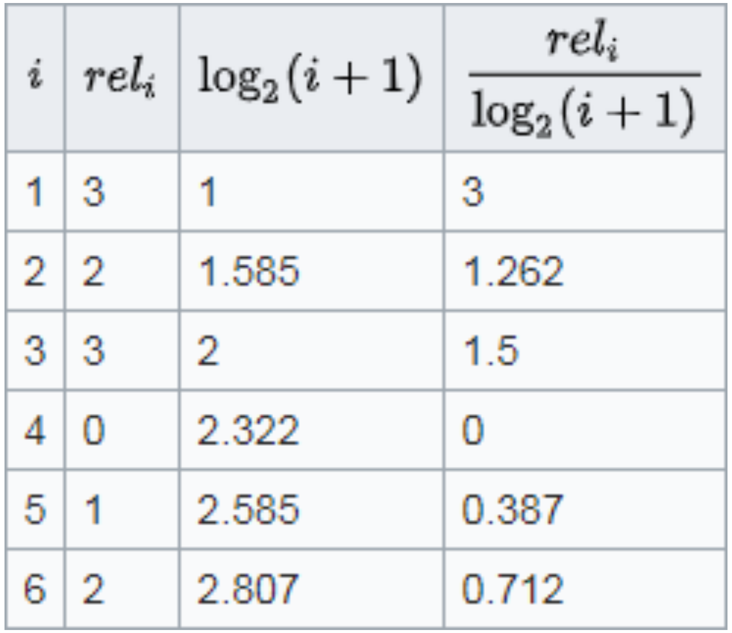
DCG_k = DCG at position k
r = rank
rel_r = graded relevance of the result at rank r

DCG Example

- Presented with a list of documents in response to a search query, an experiment participant is asked to judge the relevance of each document to the query. Each document is to be judged on a scale of 0-3 with:
  - 0 ➔ not relevant,
  - 3 ➔ highly relevant, and
  - 1 and 2 ➔ "somewhere in between".

DCG Example

- Compute DCG



i	rel_i	$\log_2(i+1)$	$\frac{rel_i}{\log_2(i+1)}$
1	3	1	3
2	2	1.585	1.262
3	3	2	1.5
4	0	2.322	0
5	1	2.585	0.387
6	2	2.807	0.712

$$\mathrm{DCG_6} = \sum_{i=1}^{6} \frac{rel_i}{\log_2(i+1)} = 3 + 1.262 + 1.5 + 0 + 0.387 + 0.712 = 6.861$$

Which system is better?

- 3,3,3,2,2,2 or 3,2,3,0,1,2 ?

Results from System 1		
rel_i	$\log_2(i+1)$	$\frac{rel_i}{log_2(i+1)}$
3.00	1.00	3.00
3.00	1.58	1.89
3.00	2.00	1.50
2.00	2.32	0.86
2.00	2.58	0.77
2.00	2.81	0.71
		8.74

Results from System 2		
rel_i	$\log_2(i+1)$	$\frac{rel_i}{log_2(i+1)}$
3.00	1.00	3.00
2.00	1.58	1.26
3.00	2.00	1.50
0.00	2.32	0.00
1.00	2.58	0.39
2.00	2.81	0.71
		6.86

Which system is better?

- 3,2,3,0,1,2 or
- 3,3,3,2,2,2,1,0

What if there are unequal number of documents?

- Ideal DCG at 6 is (the best value) DCG for 3,3,3,2,2,2
- Normalize DCG with Ideal DCG value.
- NDCG for System 1 = DCG/IDCG =1.
- NDCG for System 2 = 0.785.

For a set of queries Q, we average the NDCG.