



Processamento  
e Recuperação  
de Informação

Evaluation  
and Relevance

Precision vs.  
Recall

Other  
Measures

Obtaining the  
Ground Truth

Evaluation of  
Classifiers

# Processamento e Recuperação de Informação

## Evaluation of IR and IE Systems

Departamento de Engenharia Informática  
Instituto Superior Técnico

1º Semestre  
2018/2019



# Bibliography

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# IR System Evaluation

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## Why evaluate?

- Measure the benefit of using an IR system
- Measure how well an IR system fulfills its goal
- Compare IR systems

## What to evaluate?

- Collection coverage
- Processing time
- Output presentation
- User effort
- Recall and Precision



# Elements of an information retrieval performance evaluation experiment

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## The Cranfield Paradigm

An IR experiment, as devised by Cyril Cleverdon (1950s), must include:

- 1 A reference collection
- 2 Relevance judgments
- 3 An evaluation metric



# Relevant Documents

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## Recall and Precision

Measure the ability of a system to return **relevant** documents.

## Relevance

- Subjective notion
- Usually **evaluated by a set of experts**



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# Evaluating Prediction

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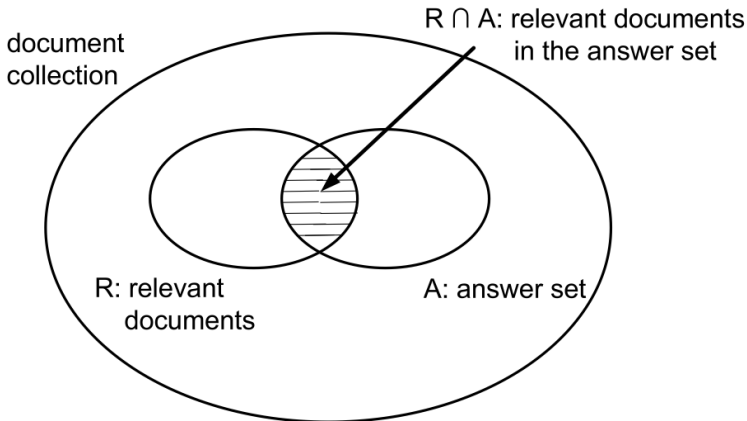
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# Measuring Precision and Recall

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## Definition

Let  $A$  be the set of documents retrieved for query  $Q$ .

Let  $R$  be the set of documents that are relevant to query  $Q$ .

**Precision** is the proportion of retrieved documents that are relevant, i.e.:

$$Pr = \frac{|R \cap A|}{|A|}$$

**Recall** is the proportion of relevant documents retrieved, i.e.:

$$Re = \frac{|R \cap A|}{|R|}$$



# Precision-Recall Curves

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- Retrieved documents are ordered  $\Rightarrow$  we are interested in measuring how precision changes as recall increases

## Example

Let  $A = \{d_1, d_2, d_3, d_4, d_5, d_6, d_7, d_8, d_9, d_{10}\}$  be an ordered set of retrieved documents, for a query  $Q$ .

Let  $R = \{d_2, d_5, d_8, d_{15}\}$  be the set of relevant documents for query  $Q$ .

| $Re$ | $Pr$ |
|------|------|
| 0.25 | 0.50 |
| 0.50 | 0.40 |
| 0.75 | 0.38 |



# Interpolated Precision-Recall

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- Precision is usually measured at 10 standard recall points: 0%, 10%, 20%, ..., 90%, 100%

- Precision at  $r^0\%$  recall is defined as

$$P(r) = \max_{i \geq r} P(i)$$

- Precision is zero after no more relevant documents are found



# Interpolated Precision-Recall (cont.)

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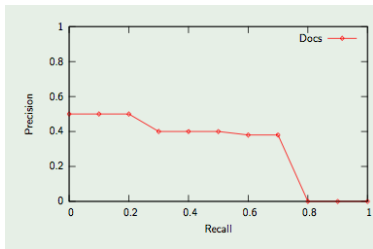
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Let  $A = \{d_1, d_2, d_3, d_4, d_5, d_6, d_7, d_8, d_9, d_{10}\}$  be an ordered set of retrieved documents, for a query  $Q$ . Let  $R = \{d_2, d_5, d_8, d_{15}\}$  be the set of relevant documents for query  $Q$ .

| <i>Re</i> | <i>Pr</i> |
|-----------|-----------|
| 0.00      | 0.50      |
| 0.10      | 0.50      |
| 0.20      | 0.50      |
| 0.30      | 0.40      |
| 0.40      | 0.40      |
| 0.50      | 0.40      |
| 0.60      | 0.38      |
| 0.70      | 0.38      |
| 0.80      | 0.00      |
| 0.90      | 0.00      |
| 1.00      | 0.00      |





# Interpolated Precision-Recall (cont.)

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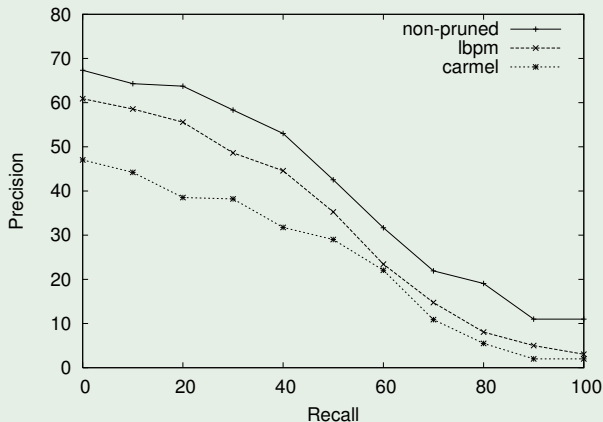
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## Example





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# $P@N$ , R-precision

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## $P@N$ – Precision at the $N$ -th retrieved document

Most commonly used

- $P@5$ ,
- $P@10$
- $P@20$

Usefull for Web retrieval

**R-precision** - Precision at the  $R$ -th document, where  $R$  is the number of relevant documents



# F-measure

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Harmonic mean of precision and recall:

$$F_1 = \frac{2 \times Re \times Pr}{Re + Pr}$$





# AP, MAP

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- **AP** - Average of the values for the precision at each recall point

$$AP = \frac{\sum_{i=1}^N Pr@i \times R_i}{|R|}$$

where  $R_i = 1$  if document at rank  $i$  is relevant and  $R_i = 0$  otherwise.

- **MAP** - Mean Average Precision

$$MAP = \frac{\sum_{q=1}^Q AP_q}{Q}$$

- AP can also be interpolated



# Discounted Cumulative Gain

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## Cumulative gain: sum the relevance weights

- **DCG** - Discounted cumulative gain

$$\text{DCG}_p = R_1 + \sum_{i=2}^p \frac{R_i}{\log_2 i}$$

where  $R_i = 1$  if document at rank  $i$  is relevant and  $R_i = 0$  otherwise.

- **nDCG** - Normalized discounted cumulative gain

$$\text{nDCG}_p = \frac{\text{DCG}_p}{\text{Ideal DCG}_p}$$



# MRR

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## MRR - Mean Reciprocal Rank

$$\text{MRR} = \frac{1}{N} \sum_{i=1}^N \frac{1}{\text{rank}_i}$$

where  $\text{rank}_1$  is the rank of the first relevant document.



# ERR

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## ERR - Expected Reciprocal Rank

Assumes a cascade model for user browsing.

$$\begin{aligned}\text{ERR} &= \sum_{i=1}^N \frac{1}{N} \times P(\text{user stops at position } i) \\ &= \sum_{i=1}^N \frac{1}{N} \times \prod_{j=1}^{N-1} (1 - R_j) R_N\end{aligned}$$

where  $R_i = 1$  if document at rank  $i$  is relevant and  $R_i = 0$ , or instead the result of mapping from relevance grades to probability of relevance.

$$R(g) = \frac{2^g - 1}{2^{g_{\max}}}$$



# Ranking Comparison

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## Spearman Coefficient

Computes the difference between the positions of a same document in two rankings

$$\rho(X, Y) = 1 - \frac{6 \sum_{i=1}^N d_i^2}{N(N^2 - 1)}$$

where  $d_i = \text{rank}(X)_i - \text{rank}(Y)_i$  is the difference in rankings of document  $i$ .



# Ranking Comparison (cont.)

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## Kendall's Tau

Let  $(x_1, y_1), (x_2, y_2), \dots, (x_N, y_N)$ , where each  $x_i$  is the rank of document  $i$  in ranking  $X$ , and  $y_i$  is the rank of document  $i$  in ranking  $Y$ .

$$\tau = \frac{|\text{concordant pairs}| - |\text{discordant pairs}|}{N(N-1)/2}$$

where a pair  $(x_i, y_i)$  is concordant with  $(x_j, y_j)$  if either:

$$\begin{cases} x_i > x_j \wedge y_i > y_j \\ x_i < x_j \wedge y_i < y_j \end{cases}$$

and discordant if either:

$$\begin{cases} x_i > x_j \wedge y_i < y_j \\ x_i < x_j \wedge y_i > y_j \end{cases}$$



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# Reference Collections

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**TREC** Various collections of documents (Ad hoc, Web, Blog, Clinical Decision Support, ...)

**CACM** Articles from Communications of the ACM

**ISI** Information science papers

**CFC** Cystic Fibrosis Collection

...

- Standards for research in IR
- Provide sets queries + evaluated documents





# Human Experimentation in the Lab

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- User preferences are affected by the characteristics of the user interface (UI)
  - For instance, the users of search engines look first at the upper left corner of the results page.
  - Changing the layout is likely to affect the assessment made by the users and their behavior.
- Proper evaluation of the user interface requires going beyond the framework of the Cranfield experiments



# A/B Testing

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- A/B testing consists of displaying to selected users a modification in the layout of a page
  - The group of selected users constitute a fraction of all users such as, for instance, 1%
  - The method works well for sites with large audiences
- By analysing how the users react to the change, it is possible to analyse if the modification proposed is positive or not

A/B testing provides a form of human experimentation, even if the setting is not that of a lab

## Amazon Mechanical Turk

### Make Money by working on HITs

HITs - *Human Intelligence Tasks* - are individual tasks that you work on. [Find HITs now.](#)

As a Mechanical Turk Worker you:

- Can work from home
- Choose your own work hours
- Get paid for doing good work



### Get Results from Mechanical Turk Workers

Ask workers to complete HITs - *Human Intelligence Tasks* - and get results using Mechanical Turk. [Get started.](#)

As a Mechanical Turk Requester you:

- Have access to a global, on-demand, 24 x 7 workforce
- Get thousands of HITs completed in minutes
- Pay only when you're satisfied with the results



<https://www.mturk.com>

- The participants execute human intelligence tasks, called HITs, in exchange for small sums of money
- The tasks are filed by requesters who have an evaluation need
- While the identity of participants is not known to requesters, the service produces evaluation results of high quality (except for **free-loaders**, etc)



# Evaluation using Clickthrough Data (1)

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## A promising alternative...

The data can be obtained by observing how frequently the users click on a given document, when it is shown in the answer set for a given query

## Attractive, because...

The data can be collected at a low cost without overhead for the use



## Evaluation using Clickthrough Data (2)

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### Click models

An accurate user model, which closely reflects users' interactions with the retrieval system, is essential for developing a good relevance metric from clickthrough data.

**Example:** Cascade model used in ERR metric, corresponding to

$$\prod_{i=1}^{N-1} (1 - R_i) R_N,$$

where the values  $R_i$  (i.e., document satisfies the user with probability  $R_i$ ) can be estimated by maximum likelihood on the click logs.



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# Classifier Evaluation

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- Previous lectures have shown that tasks such as document classification or information extraction from text can be modeled as classification problems
  - I.e., techniques in this section also apply to IE systems
- Goal in supervised classification is the minimization of classification error on test data
- We can evaluate through measures like recall, precision, and accuracy (i.e., one minus error)
  - But classification tasks can involve more than two classes (i.e., more than distinguishing relevant from non-relevant)



# Confusion Matrix

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- $M[i, j]$  is the number of test documents belonging to class  $i$  which were assigned to class  $j$
- Perfect classifier: diagonal elements  $M[i, i]$  would be nonzero
- Example:

$$M = \left\{ \begin{array}{c|c|c} 5 & 0 & 0 \\ \hline 1 & 3 & 0 \\ \hline 1 & 2 & 4 \end{array} \right\}$$

- If  $M$  is large, we use

$$\text{accuracy} = \sum_i M[i, i] / \sum_{i,j} M[i, j]$$

- Notice that accuracy is not a good measure for *small* classes





# Micro-Averaged Precision

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In a problem with  $n$  classes, let  $C_i$  be the number of documents in class  $i$  and let  $C'_i$  be the number of documents estimated to be of class  $i$  by the classifier

- **Micro-averaged precision** is defined as

$$\frac{\sum_{i=1}^n C'_i \cap C_i}{\sum_{i=1}^n C'_i}$$

- **Micro-averaged recall** is defined as

$$\frac{\sum_{i=1}^n C'_i \cap C_i}{\sum_{i=1}^n C_i}$$

- Micro-averaged precision/recall measures correctly classified documents, thus favoring large classes



# Macro-Averaged Precision

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In a problem with  $n$  classes, let  $P_i$  and  $R_i$  be the precision and recall, respectively, achieved by a classifier for class  $i$

- **Macro-averaged precision** is defined as

$$\frac{1}{n} \sum_{i=1}^n P_i$$

- **Macro-averaged recall** is defined as

$$\frac{1}{n} \sum_{i=1}^n R_i$$

- Macro-averaged precision/recall measures performance per class, giving all classes equal importance



# $F_1$ measure

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The  $F_1$  measure is also commonly used

$$F_1 = \frac{2 \times P_i \times R_i}{P_i + R_i}$$

- Harmonic mean between precision and recall
- Discourages classifiers that trade one for the other



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# Questions?