Information Retrieval

Computer Science Tripos Part II

Evaluation

Stephen Clark
Natural Language and Information Processing (NLIP) Group

Introduction to Evaluation

- We want to know how well a retrieval sytem performs
- What is "performance" in an IR setting?
  - For a DBMS, performance is data retrieval time, since search is exact
  - For an IR system, search is inexact
    - still interested in **retrieval time**
    - also interested in **retrieval accuracy**
    - may be interested in other factors: **ease of use**, **financial**, **presentation of documents**, **help in formulating queries**, ...
- IR evaluation has focused primarily on **retrieval accuracy**: how good is a system at returning documents which are relevant to the user need?

History

- Evaluation has been a key issue in IR since the 60's
  - consequence of the empirical approach taken to IR
- Early work compared manual vs. automatic indexing
- The TREC competitions (over the last decade) have been very influential

Difficulties with IR Evaluation

- "Relevance" is difficult to define precisely
  - who makes the judgement?
  - humans are not very consistent
- Information need may not be clear – so how can we determine if it's been satisfied?
- Difficult to separate the user from the system, especially in interactive retrieval
- Judgements depend on more than just document and query
- For large document collections, difficult to determine the set of relevant documents

Evaluation under Laboratory Conditions

- Evaluation has been used as an analytical tool in an **experimental** setting
  - e.g. to determine if one weighting scheme is better than another
  - implies control of experimental variables
- Abstraction of IR system from operational setup
- Largely ignored interaction with the user
- Concentration on measures like **precision** and **recall** using standard **test collections**

TREC

- **T**ext **Re**trieval **C**onference
  - Established in 1992; annual conference
  - designed to evaluate **large-scale** IR
    (2 gigabyte document collections, up to a million documents)
  - Run by NIST (US technology agency)
  - In 1992 25 organisations – industrial and academic – participated
  - In 2003 93 groups participated from 22 different countries
  - http://trec.nist.gov/

Format of TREC

- TREC consists of IR research **tracks**
  - ad-hoc, filtering, cross-language, genomics, HARD, interactive, question-answering, terabyte, video, web
    - HARD: High Accuracy Retrieval from Documents; uses information about, and interaction with, user
- Timetable:
  - Spring: researchers train/develop systems
  - Summer: system is run on final test collection and results submitted to NIST for evaluation
  - November: conference takes place to compare results
- Competition encourages research and enables successful approaches to be adopted for the next round
  - does it work?

Test Collections

- Test collections used to compare retrieval performance of systems / techniques
  - set of documents
  - set of queries (or **topics**)
    * typically text description of user need, or information request, from which final query is constructed
  - set of relevance judgements
- How to compare performance?
  - results (set of returned documents, usually ranked) compared using some performance measure
  - **precision** and **recall** most common measures
- Ideally use multiple test collections
  - performance can be collection-specific

Use of Test Collections

- Before TREC, IR testing was on a relatively small scale
- Earlier work tended to use the same test material to maintain comparability
- Large test collections (both queries and documents) are important
  - to ensure statistical significance of results
  - to convince commercial system operators of the validity of the results
- TREC tracks typically have hundreds of thousands of documents, and hundreds of topics

Sample TREC Query

<num> Number: 508
<title> hair loss is a symptom of what diseases

<desc> Description:
Find diseases for which hair loss is a symptom.

<narr> Narrative:
A document is relevant if it positively connects the loss of head hair in humans with a specific disease. In this context, "thinning hair" and "hair loss" are synonymous. Loss of body and/or facial hair is irrelevant, as is hair loss caused by drug therapy.

TREC Relevance Judgements

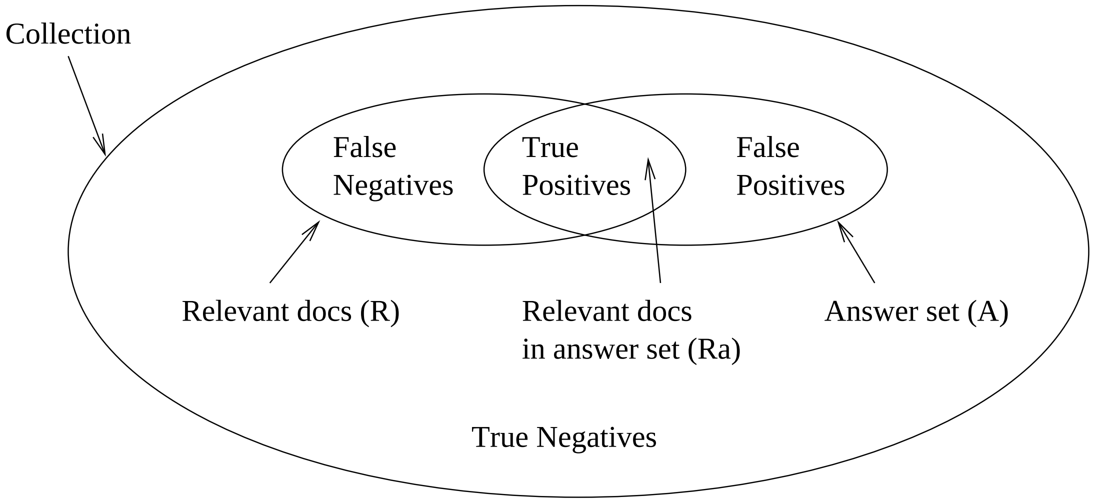
Humans decide which document–query pairs are relevant.

Determining Relevant Documents

- Did the system return all possible relevant documents?
  - need a relevance judgement for every document in the collection, for every query/topic
  - at 30s a document/topic pair, would take 6,500 hours to judge 800,000 TREC documents for one topic

- TREC solution is **pooling**
  - select N **runs** per system
  - take the top K (usually 100) documents returned by each system (according to system's ranking) for those runs
  - then assume all relevant documents are in union and manually assess this set
  - pooling found not to be bias towards systems contributing to the pool

Precision and Recall for Document Retrieval



- **Precision** $= |\text{Ra}|/|\text{A}|$
  - precision $= \hat{P}(\text{relevant}|\text{retrieved})$

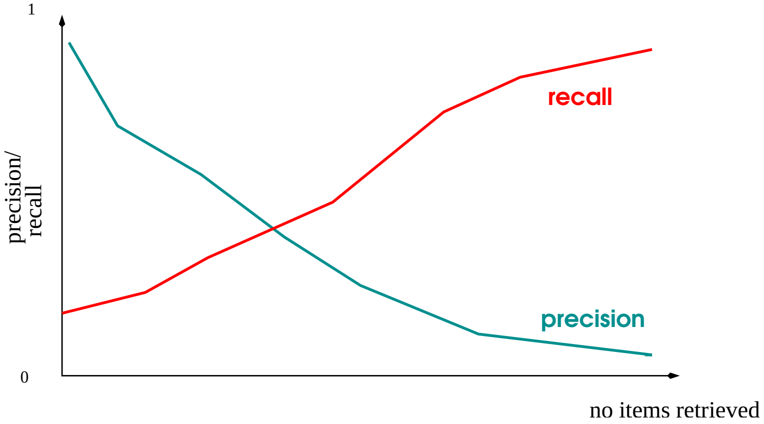
- **Recall** $= |\text{Ra}|/|\text{R}|$
  - recall $= \hat{P}(\text{retrieved}|\text{relevant})$

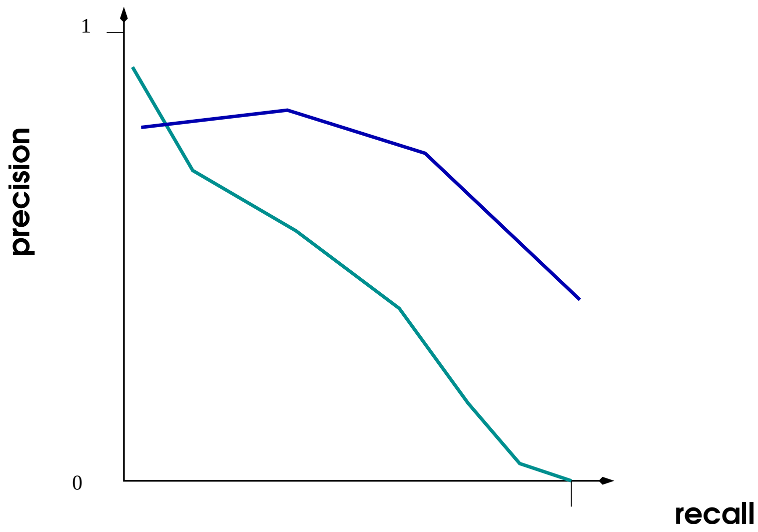
Another Representation

	relevant	not relevant
retrieved	A	B
not retrieved	C	D

- **precision** = A / (A+B)
  - $\hat{P}$(relevant|retrieved)
- **recall** = A / (A+C)
  - $\hat{P}$(retrieved|relevant)
- **miss** = C / (A+C)
  - $\hat{P}$(not-retrieved|relevant)
- **false alarm** (fallout) = B / (B+D)
  - $\hat{P}$(retrieved|not-relevant)

Recall-precision curve





- Plotting precision and recall (versus no. of documents retrieved) shows inverse relationship between precison and recall
- Precision/recall cross-over can be used as combined evaluation measure

- Plotting precision versus recall gives **recall-precision** curve
- Area under normalised recall-precision curve can be used as evaluation measure

Recall-criticality and precision-criticality

- Inverse relationship between precision and recall forces general systems to go for compromise between them

- But some tasks particularly need good precision whereas others need good recall:

Precision-critical task	**Recall-critical task**
Little time available	Time matters less
A small set of relevant documents answers the information need	One cannot afford to miss a single document
Potentially many documents might fill the information need (redundantly)	Need to see *each* relevant document
Example: web search for factual information	Example: patent search

Single Value Measures

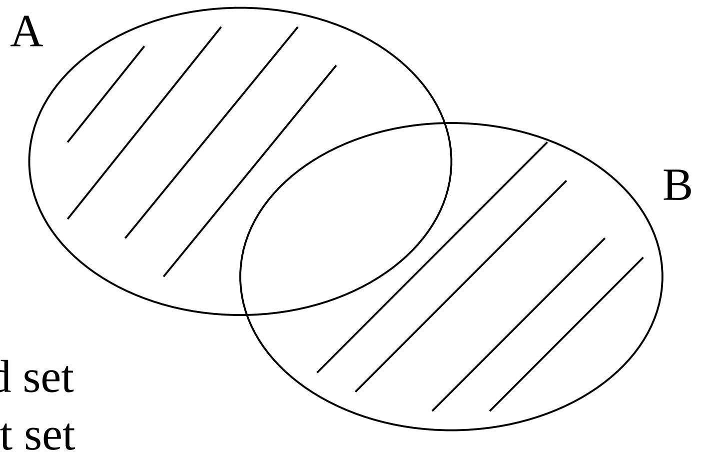
- **F-score** $= \frac{1}{\frac{1}{2}(\frac{1}{P}+\frac{1}{R})} = \frac{2PR}{P+R}$

- F-score is **harmonic mean** of P and R: inverse of average of inverses

- F-score is 1 when P = R = 1 and 0 when P or R are 0

- Penalises low values of P or R
  - it is very easy to obtain high precision (just return very few documents) or high recall (return all documents)

Geometric Interpretation of F-Measure



A is retrieved set
B is relevant set

- P = |A∩B| / |A|
- R = |A∩B| / |B|

$$
\begin{aligned}
F &= 2PR/(P+R) \\
&= 2\frac{|A \cap B|^2}{|A| \,.\, |B|} / (|A \cap B| (\frac{1}{|A|} + \frac{1}{|B|})) \\
&= \frac{2|A \cap B|}{|A| + |B|}
\end{aligned}
$$

Single Value Measures

- **E-measure** $= \frac{1}{\alpha\frac{1}{P}+(1-\alpha)\frac{1}{R}}$

- used to emphasis precision or recall
  - weighted harmonic mean of precision and recall
  - high α emphasises precision

- Transforming by $\alpha = \frac{1}{\beta^2+1}$ gives
  E $= \frac{(\beta^2+1)PR}{\beta^2 P+R}$

- $\beta = 1$ ($\alpha = \frac{1}{2}$) gives F-score

- $\beta > 1$ emphasises precision; $\beta < 1$ emphasises recall

Measure for Ranked Retrieval

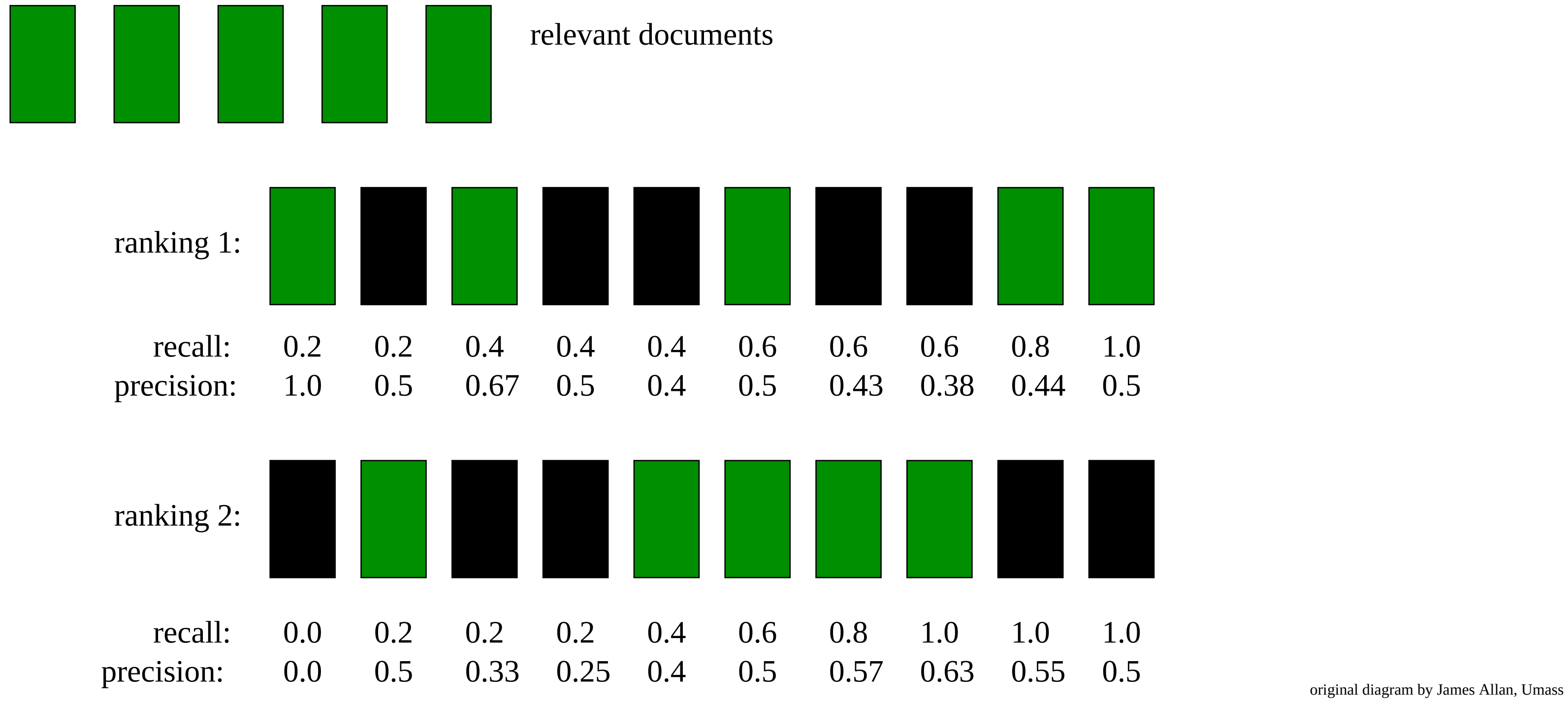
- Precision and Recall well defined for sets
- But matching can be defined as a matter of degree
  - vector space model returns similarity score for each document
- How to evaluate the quality of the rank-ordering, as well as the number and proportion of relevant documents retrieved?

Precision/Recall @ Rank

1. d_{12} 2. d_{123} 3. $\mathbf{d}_4$ 4. d_{57} 5. d_{157} 6. d_{222} 7. $\mathbf{d}_4$ 8. d_{26} 9. $\mathbf{d}_{77}$ 10. d_{90}

- Suppose there are 3 relevant documents
  - **P@n**: P@3 = 0.33, P@5 = 0.2, P@8 = 0.25
  - **R@n**: R@3 = 0.33, R@5 = 0.33, R@8 = 0.66
- Ranks chosen for reporting depend on expected quantity of documents retrieved
- Rank statistics give some indication of how quickly user will find relevant documents from ranked list
- But may want to abstract away from ranking, since size of ranking will depend on query and document set

Precision at Recall r



- r1: p @ r 0.2 = 1.0; p @ r 0.4 = 0.67; p @ r 0.6 = 0.5; p @ r 0.8 = 0.44; p @ r 1.0 = 0.5

- r2: p @ r 0.2 = 0.5; p @ r 0.4 = 0.4; p @ r 0.6 = 0.5; p @ r 0.8 = 0.57; p @ r 1.0 = 0.63

Single Value Summary

- Useful to have a single number effectiveness measure
  - easy to read and interpret
  - may want to optimise for a machine learning algorithm
- **Average precision** is popular in IR

ranking 1:

recall:	0.2	0.2	0.4	0.4	0.4	0.6	0.6	0.6	0.8	1.0	av prec = 0.62
precision:	1.0	0.5	0.67	0.5	0.4	0.5	0.43	0.38	0.44	0.5	

ranking 2:

recall:	0.0	0.2	0.2	0.2	0.4	0.6	0.8	1.0	1.0	1.0	av prec = 0.52
precision:	0.0	0.5	0.33	0.25	0.4	0.5	0.57	0.63	0.55	0.5	

Single Value Summary

- Previous measure was average precision **at seen relevant documents**
- TREC average precision also accounts for any relevant documents not retrieved
- Suppose there are 8 relevant documents in total (3 are not retrieved by either system)
  - av. prec for r1: $(1 + 0.67 + 0.5 + 0.44 + 0.5)/8 = 0.39$
- So TREC average precision also has a recall component, in that it considers all relevant documents

Averaging over Queries

- Need an evaluation measure over more than one query
- Average precision over queries for standard recall levels (0.1, 0.2, 0.3, . . ., 1.0)?
- But |Ra|/|R| rarely seen at these levels
  - if only 3 relevant documents, recall can only be 0.33, 0.67. 1
- Answer: interpolate between actual recall values to get average precision at standard recall levels
  - many possibilities for interpolation; see Modern Information Retrieval, Ch. 3

TREC's Single Value Summary

- **Average precision** for a single query is the mean of the precision after each relevant document is retrieved

- **Mean average precision** for a set of queries is the mean of the average precision scores for each query
  - popular single value metric to represent system performance over a complete query / document set

IR Performance

- Difficult to raise performance in both precision and recall (precision/recall trade-off)
  - any improvement in precision typically results in a decrease in recall, and vice versa

- Even with small collections, difficult to raise performance beyond 40%/40% P/R level

- With larger collections 30%/30% is more likely

- Systems using statistically based natural language indexing provide respectable performance which is hard to beat

Summary

- Focused on evaluation for ad-hoc retrieval
  - other issues arise when evaluating different tracks, e.g. QA, although typically still use P/R-based measures
- Evaluation for **interactive** tasks is more involved
- Significance testing is an issue
  - could a good result have occurred by chance?
  - is the result robust across different document sets?
  - slowly becoming more common
  - underlying population distributions unknown, so apply weak tests such as the sign test

Readings for Today

- Relevant parts of the course textbook
- Modern Information Retrieval, Ch. 3
- Readings in Information Retrieval, Ch. 4
- Information Retrieval (van Rijsbergen), Ch. 7