

Batch Evaluation

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Batch Evaluation

motivation

- Many factors affect search engine effectiveness:
 - ▶ **Queries:** some queries are more effective than others
 - ▶ **Corpus:** the number of documents that are relevant to a query will vary across collections
 - ▶ **Relevance judgements:** relevance is user-specific (i.e., subjective)
 - ▶ **The IR system:** the retrieval model, the document representation (e.g., stemming, stopword removal), the query representation

Batch Evaluation

motivation

- Comparing different IR systems requires a controlled experimental setting
- **Batch evaluation:** vary the IR system, but hold everything else constant (queries, corpus, relevance judgements)
- Evaluate systems using metrics that measure the quality of a system's output ranking
- Known as the Cranfield Methodology
 - ▶ Developed in the 1960's to evaluate manual indexing systems

Batch Evaluation

overview

- Collect a set of queries (e.g., 50)
- For each query, describe a hypothetical information need
- For each information need, have human assessors determine which documents are relevant/non-relevant
- Evaluate systems based on the quality of their rankings
 - ▶ **evaluation metric:** describes the quality of a ranking with known relevant/non-relevant docs

Batch Evaluation

test collections

- Batch-evaluation uses a **test collection**
 - ▶ A set of queries with descriptions of their underlying information need
 - ▶ A collection of documents
 - ▶ A set of query-document relevance judgements
 - ▶ For now, assume binary: judgements relevant/non-relevant

Batch Evaluation

test collections

- Where do the queries come from?
 - ▶ query-logs, hypothetical users who understand the search environment, etc.
 - ▶ should reflect queries issued by “real” users
- Where do the documents come from?
 - ▶ harvested from the Web, provided by stakeholder organizations, etc.
- How are documents judged relevant/non-relevant?
 - ▶ judged by expert assessors using the information need description

Batch Evaluation

information need description

- **QUERY:** parenting
- **DESCRIPTION:** Relevant blogs include those from parents, grandparents, or others involved in parenting, raising, or caring for children. Blogs can include those provided by health care providers if the focus is on children. Blogs that serve primarily as links to other sites or market products related to children and their caregivers are not relevant.

(TREC Blog Track 2009)

Batch Evaluation

test collections

- Which documents should be judged for relevance?
 - ▶ Only the ones that contain all query-terms?
 - ▶ Only the ones that contain at least one query-term?
 - ▶ All the documents in the collection?

Batch Evaluation

test collections

- Which documents should be judged for relevance?
 - ▶ Only the ones that contain all query-terms?
 - ▶ Only the ones that contain at least one query-term?
 - ▶ All the documents in the collection?
- The best solution is to judge all of them
 - ▶ A document can be relevant without having a single query-term
 - ▶ But, there's a problem...

Batch Evaluation

test collections: examples

| Name | Docs. | Qrys. | Year ³ | Size, Mb | Source document |
|-------------|--------|-------|-------------------|----------|--|
| Cranfield 2 | 1,400 | 225 | 1962 | 1.6 | Title, authors, source, abstract of scientific papers from the aeronautic research field, largely ranging from 1945 to 1962. |
| ADI | 82 | 35 | 1968 | 0.04 | A set of short papers from the 1963 Annual Meeting of the American Documentation Institute. |
| IRE-3 | 780 | 34 | 1968 | — | A set of abstracts of computer science documents, published in 1959–1961. |
| NPL | 11,571 | 93 | 1970 | 3.1 | Title, abstract of journal papers |
| MEDLARS | 450 | 29 | 1973 | — | The first page of a set of MEDLARS documents copied at the National Library of Medicine. |
| Time | 425 | 83 | 1973 | 1.5 | Full-text articles from the 1963 edition of Time magazine. |

(Sanderson, 2010)

Batch Evaluation

test collections: examples

| Name | Docs. | Qrys. | Year ⁹ | Size, Mb | Source document |
|--------|--------|-------|-------------------|----------|--|
| INSPEC | 12,684 | 77 | 1981 | — | Title, authors, source, abstract, and indexing information from Sep to Dec 1979 issues of Computer and Control Abstracts. |
| CACM | 3,204 | 64 | 1983 | 2.2 | Title, abstract, author, keywords, and bibliographic information from articles of Communications of the ACM, 1958–1979. |
| CISI | 1,460 | 112 | 1983 | 2.2 | Author, title/abstract, and co-citation data for the 1,460 most highly cited articles and manuscripts in information science, 1969–1977. |
| LISA | 6,004 | 35 | 1983 | 3.4 | Taken from the Library and Information Science Abstracts database. |

(Sanderson, 2010)

Batch Evaluation

test collections: examples

- **GOV2 (2004)**
 - ▶ 25,000,000 Web-pages
 - ▶ Crawl of entire “.gov” Web domain
- **BLOG08 (January 2008 - February 2009)**
 - ▶ 1,303,520 blogs “polled” once a week for new posts
 - ▶ 28,488,766 posts
- **ClueWeb09 (2009)**
 - ▶ 1,040,809,705 Web-pages

Batch Evaluation

test collections

- Which documents should be judged for relevance?
 - ▶ Only the ones that contain all query-terms?
 - ▶ Only the ones that contain at least one query-term?
 - ▶ All the documents in the collection?
- The best solution is to judge all of them
 - ▶ A document can be relevance without having a single query-term
- Is this feasible?

Batch Evaluation

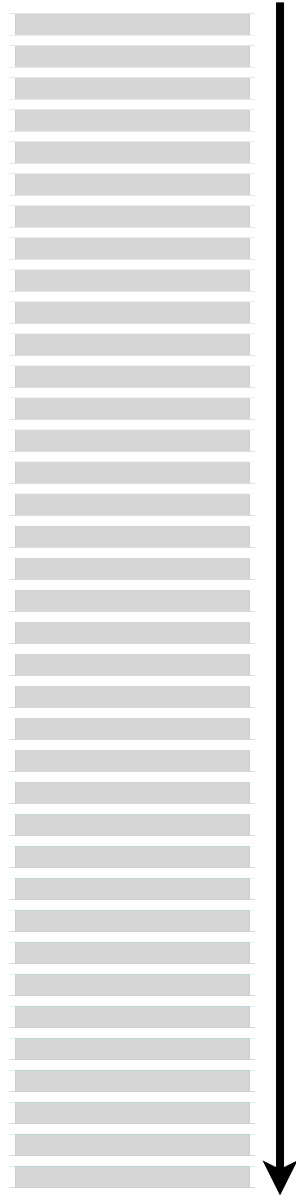
pooling

- Given (any) query, the overwhelming majority of documents are not relevant
- General Idea:
 - Identify the documents that are most likely to be relevant
 - Have assessors judge only those documents
 - Assume the remaining ones are non-relevant

Batch Evaluation

pooling

System A

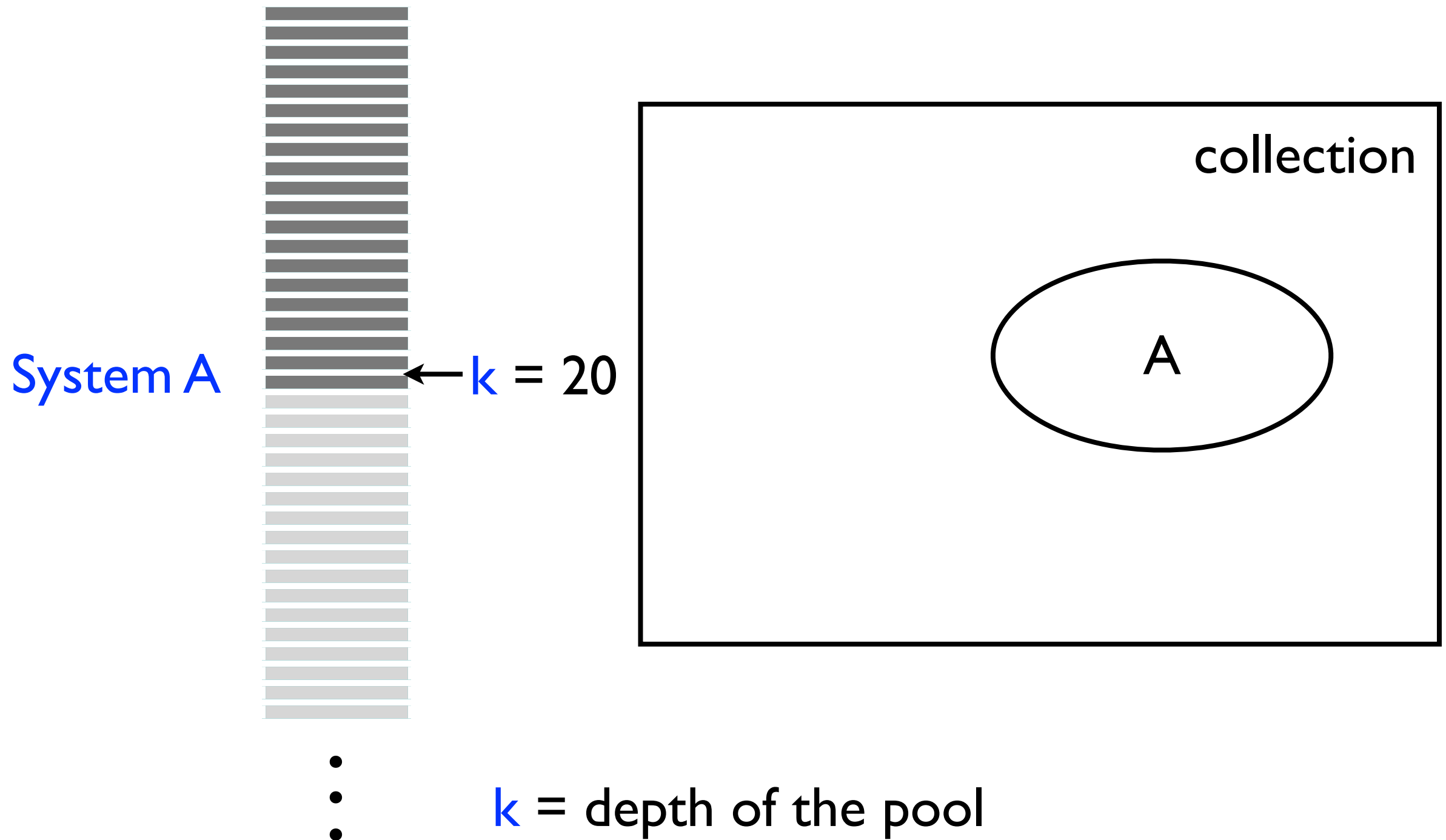


...

collection

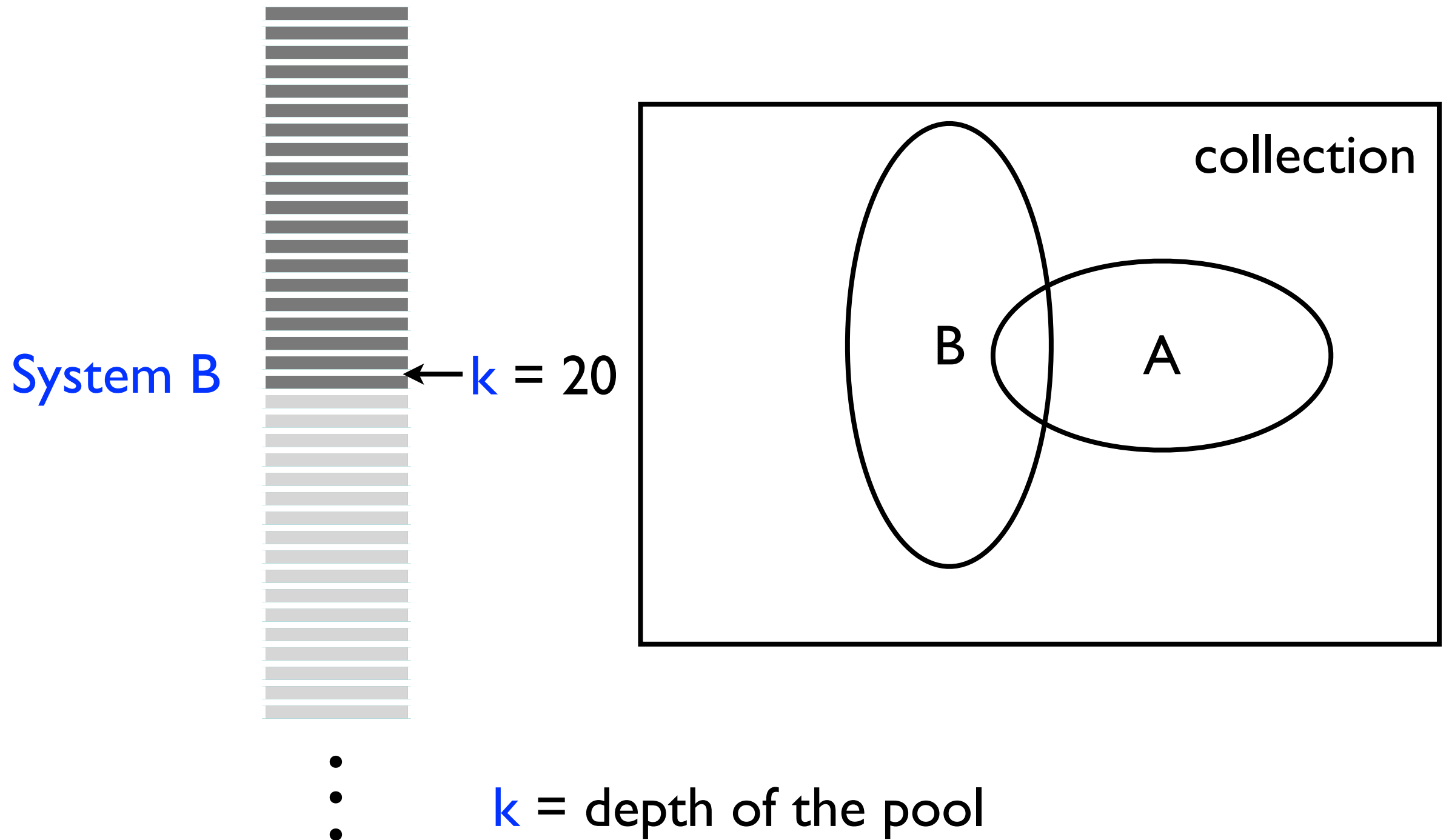
Batch Evaluation

pooling



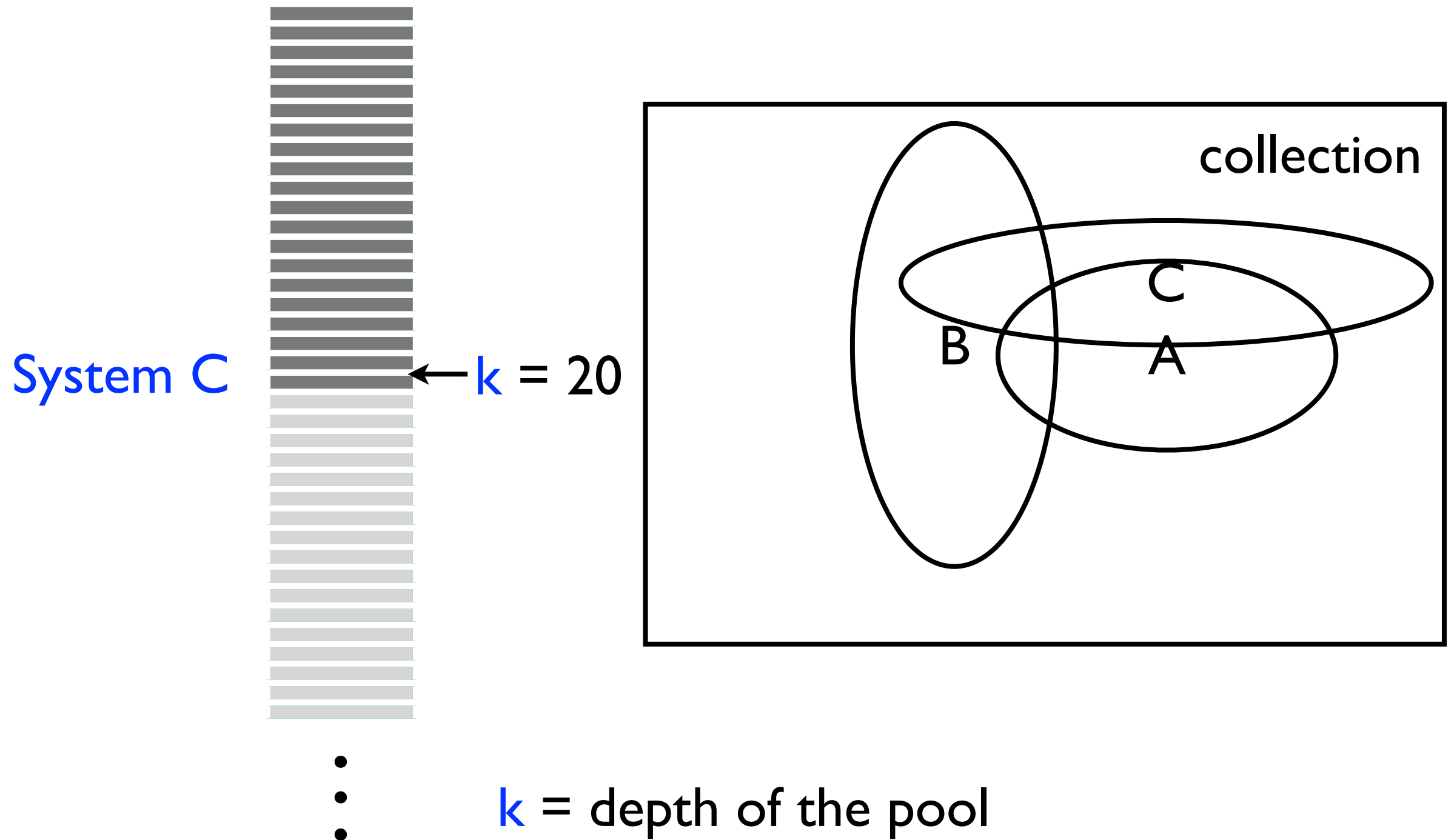
Batch Evaluation

pooling



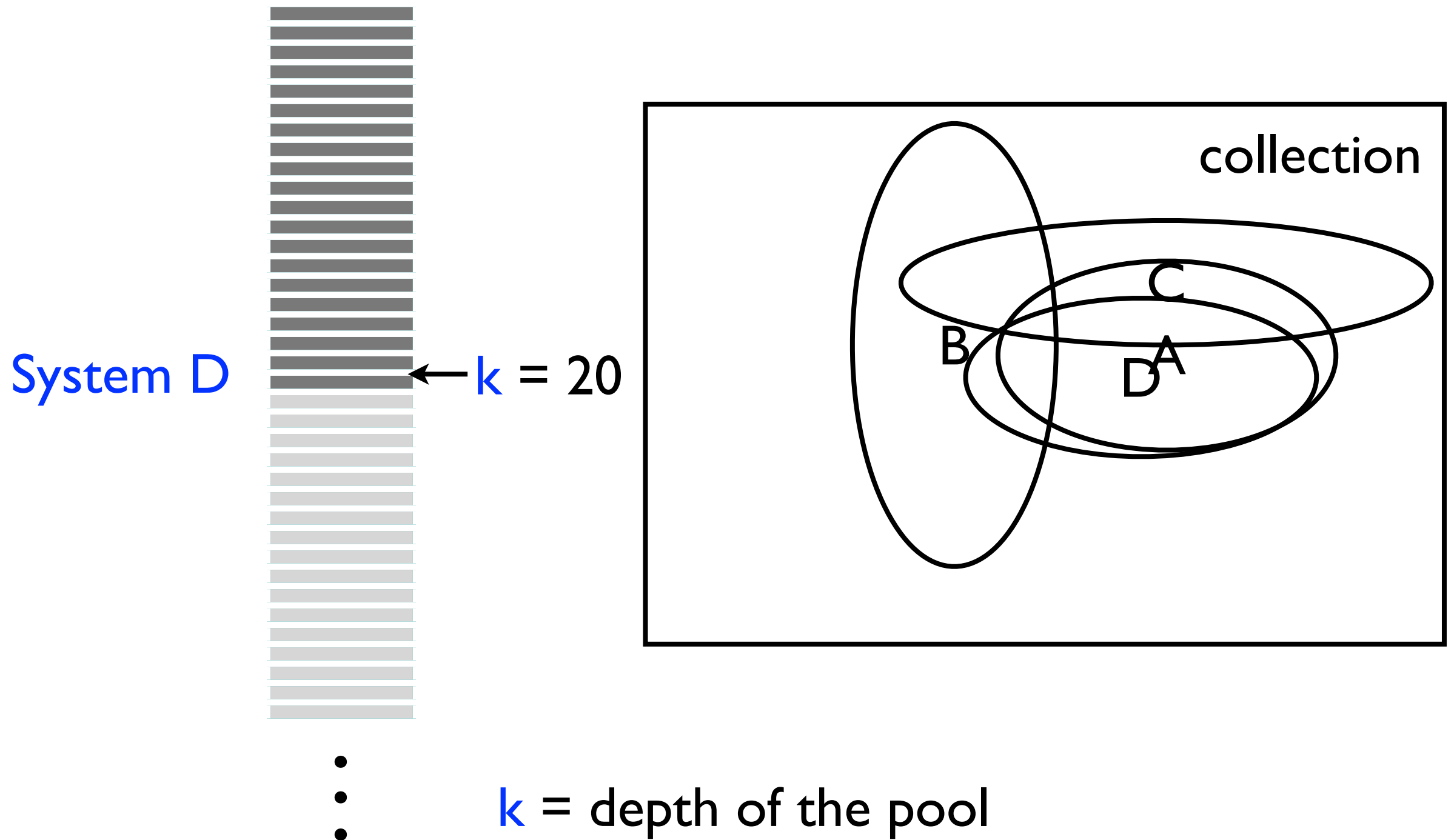
Batch Evaluation

pooling



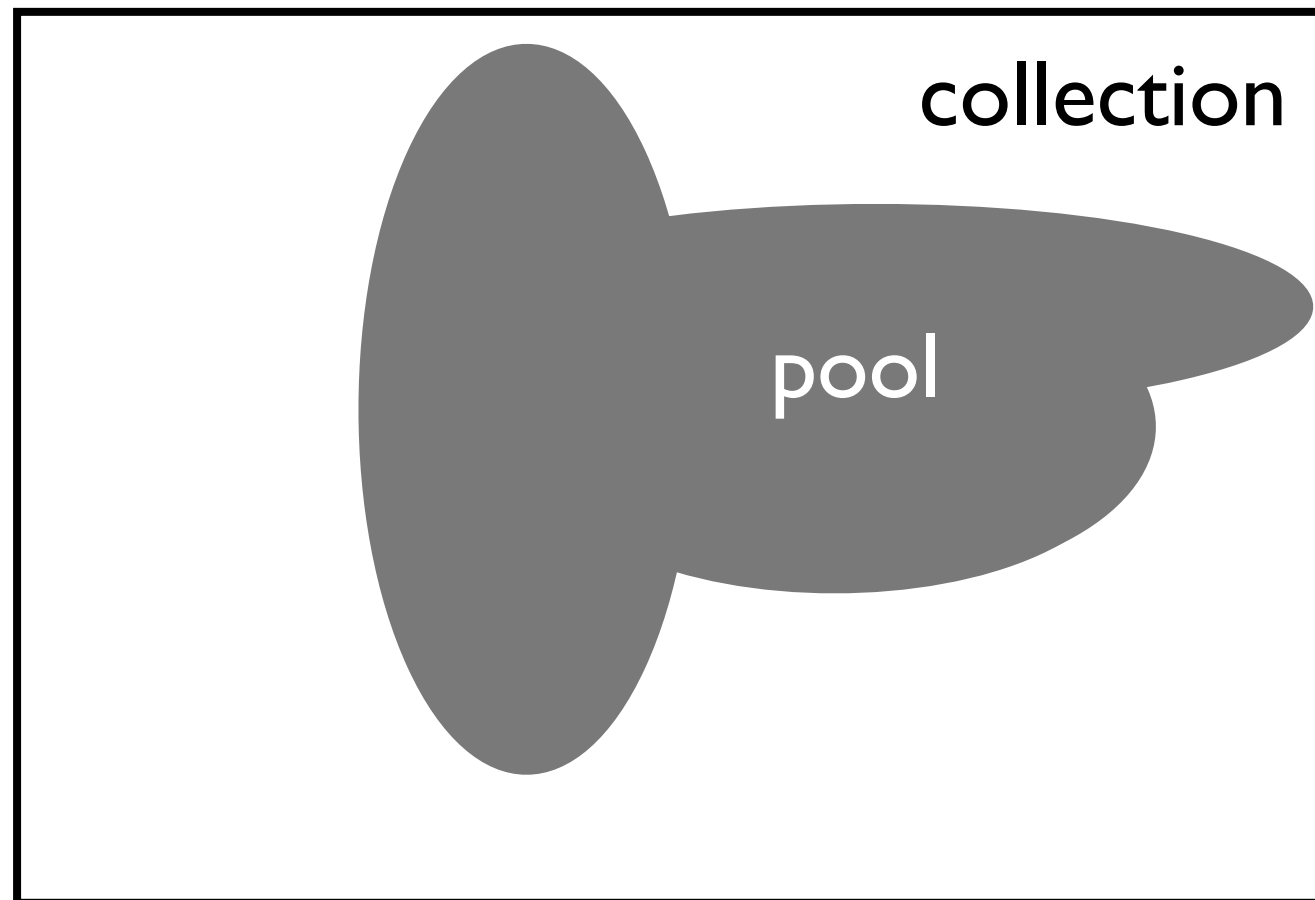
Batch Evaluation

pooling



Batch Evaluation

pooling



Batch Evaluation

pooling

- Take the top-k documents retrieved by various systems
- Remove duplicates
- Show to assessors in random order (along with the information need description)
- Assume that documents outside the pool are non-relevant

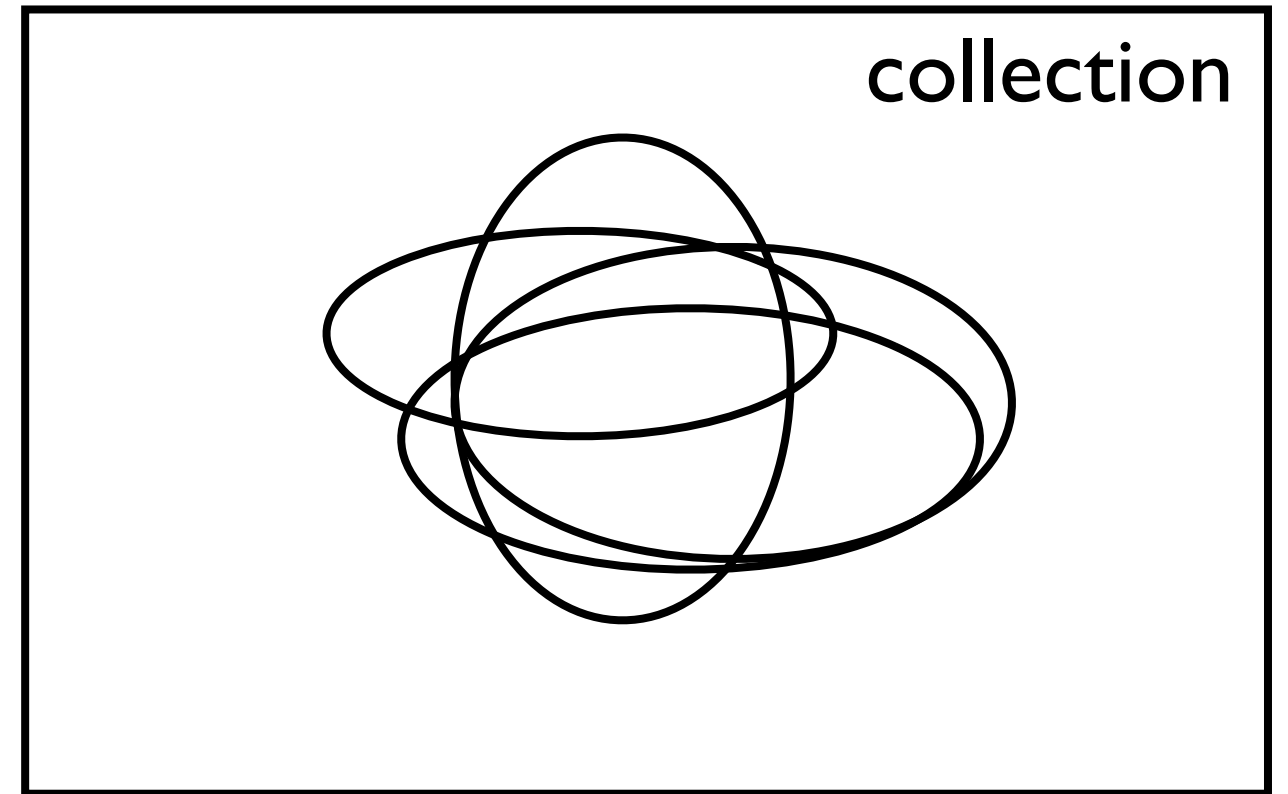
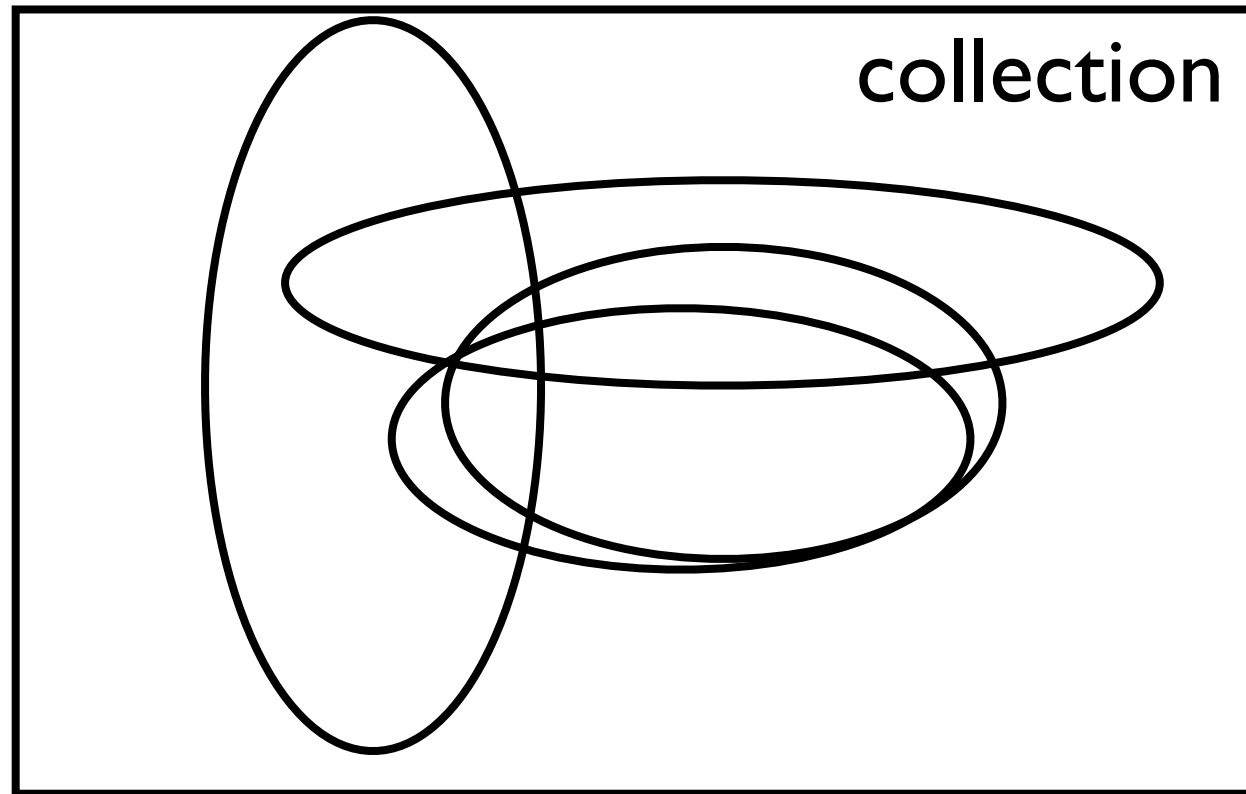
Batch Evaluation

pooling

- Usually the depth (k) of the pool is between 50 and 200 and the number of systems included in the pool is between 10 and 20
- A test-collection constructed using pooling can be used to evaluate systems that are not in the original pool
- However, what is the risk?
- And, how do we mitigate this risk?

Batch Evaluation

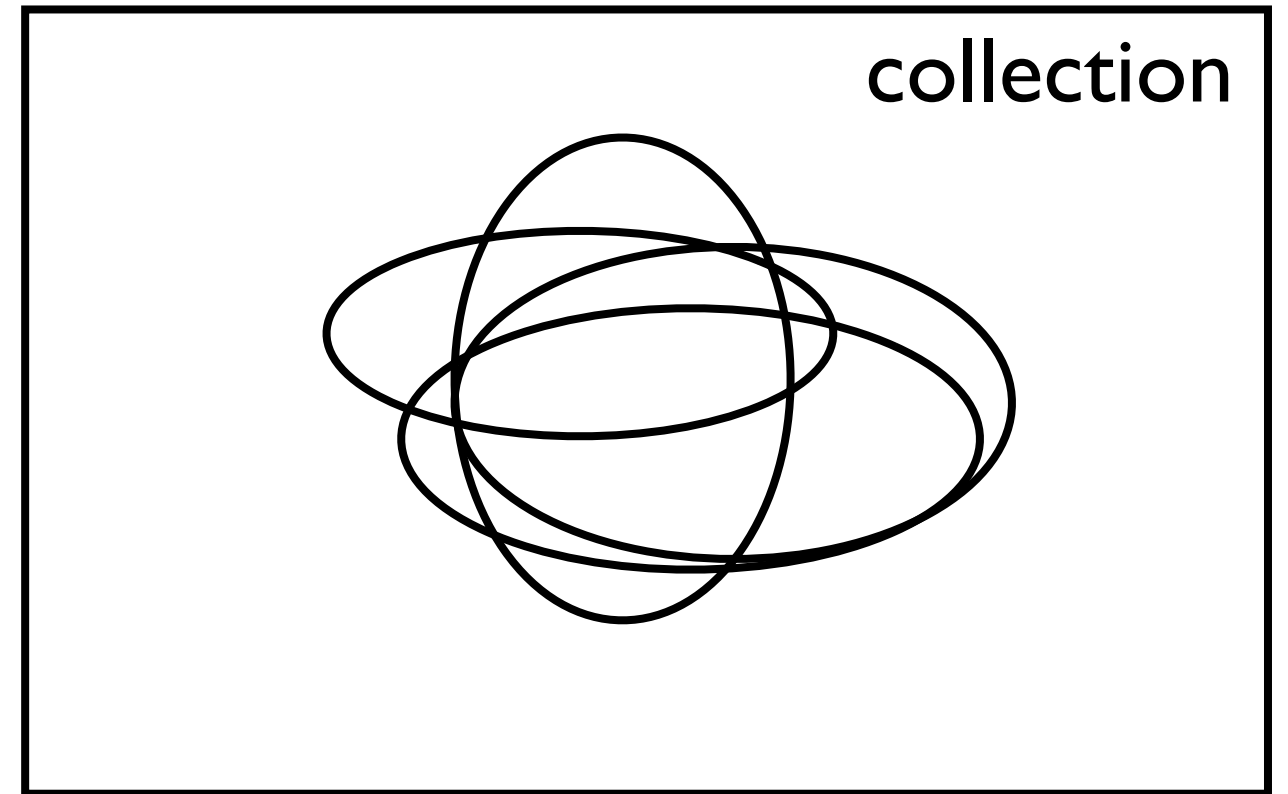
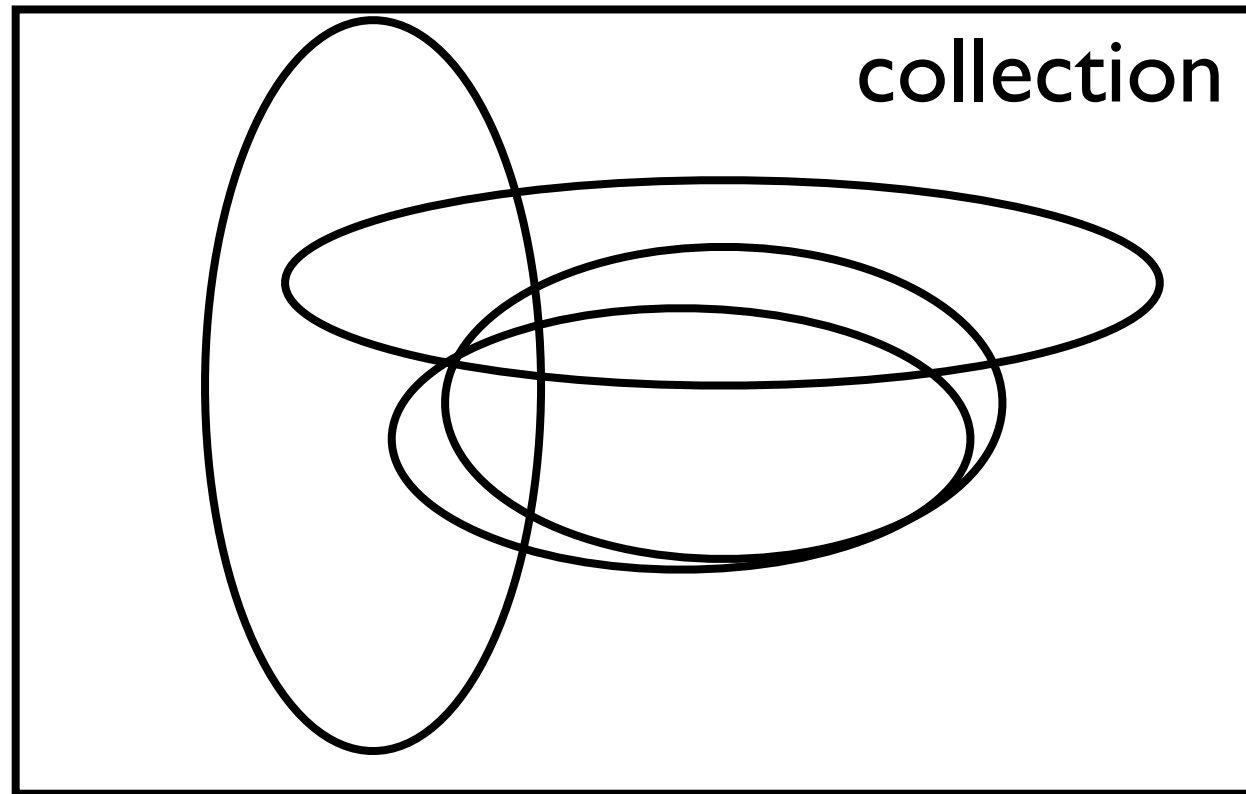
pooling



- Which selection of systems is better to include in the pool?

Batch Evaluation

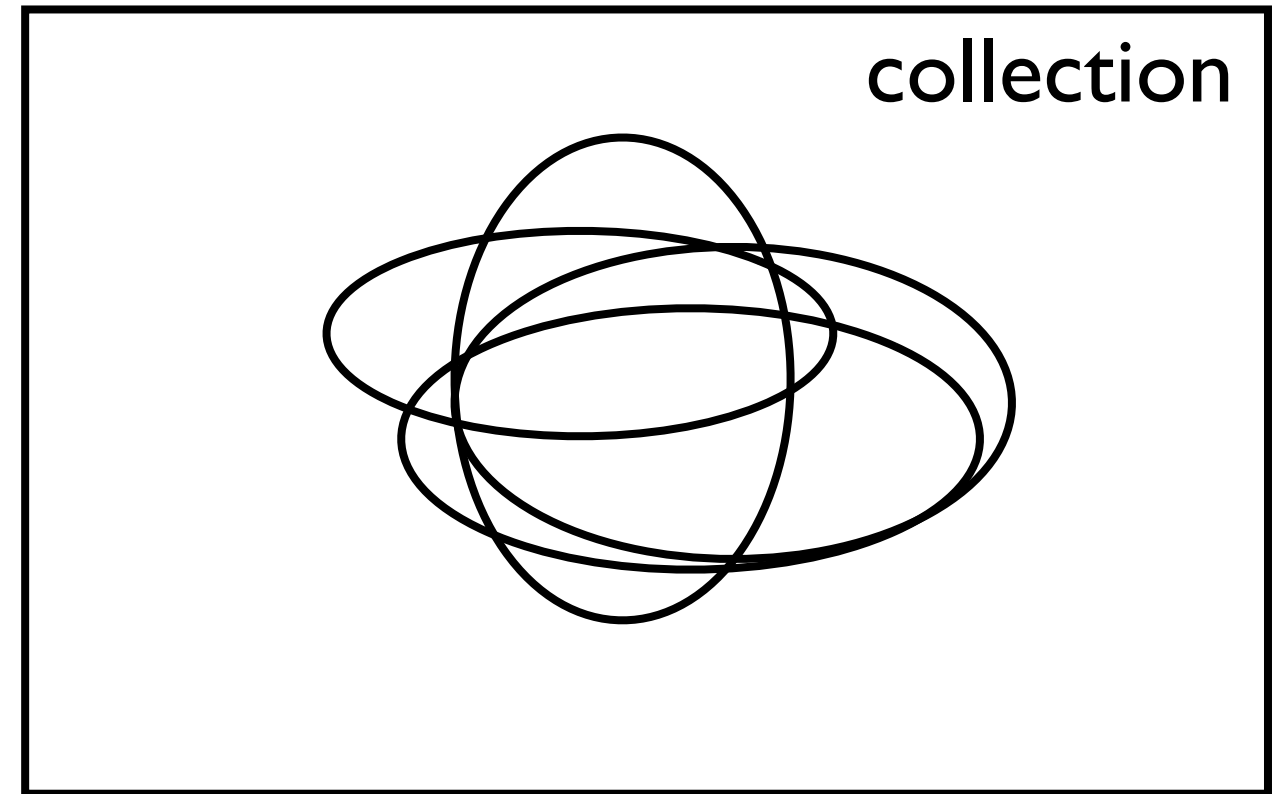
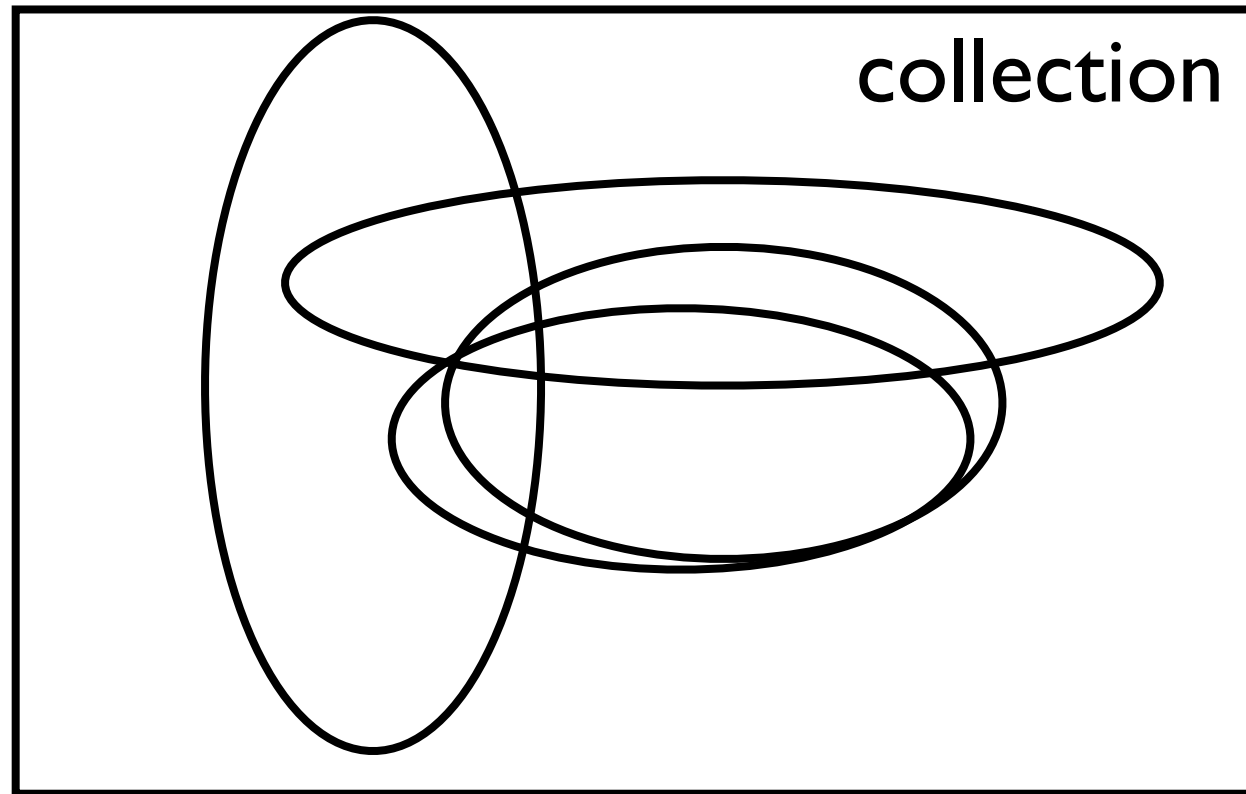
pooling



- **Strategy:** to avoid favoring systems of a particular kind, we want to construct the “pool” using systems with varying search strategies

Batch Evaluation

pooling



- How does pooling affect the accuracy with which we can compute precision and recall?
- Two scenarios: the system was part of the pool and not part of the pool

Evaluation Metrics

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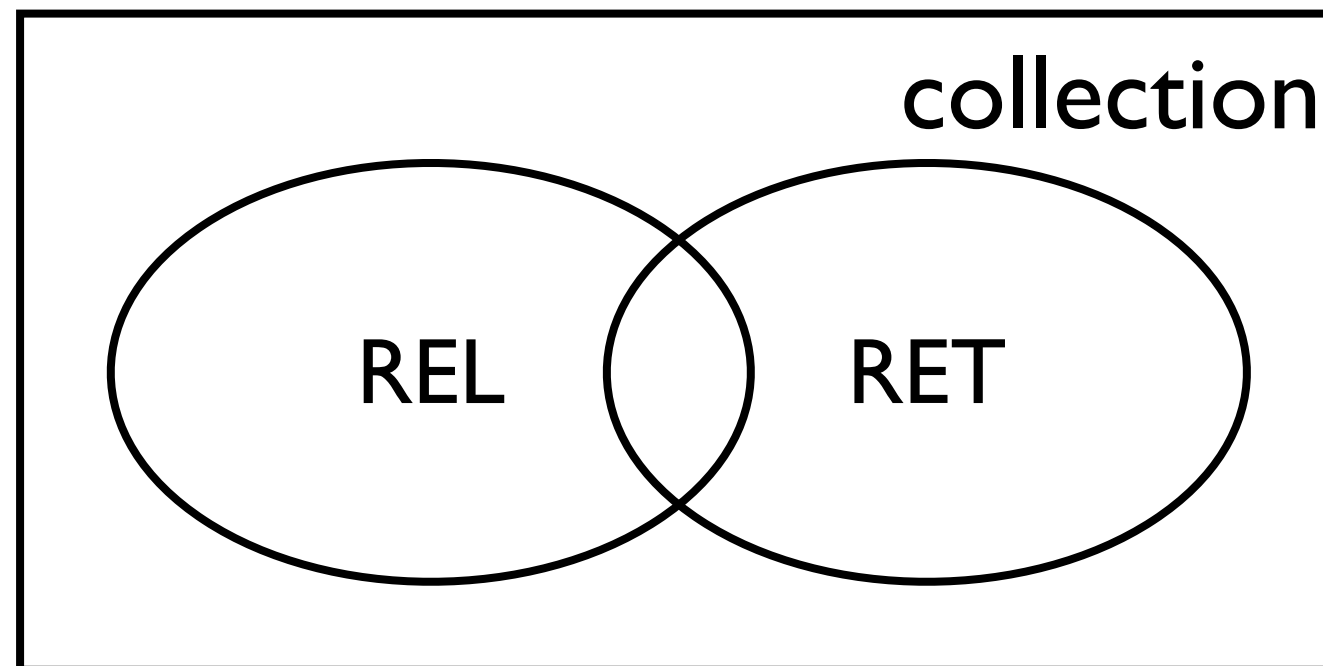
evaluation metrics

- At this point, we have a set of queries, with identified relevant and non-relevant documents
- The goal of an **evaluation metric** is to measure the quality of a particular ranking of known relevant/non-relevant documents

Set Retrieval

precision and recall

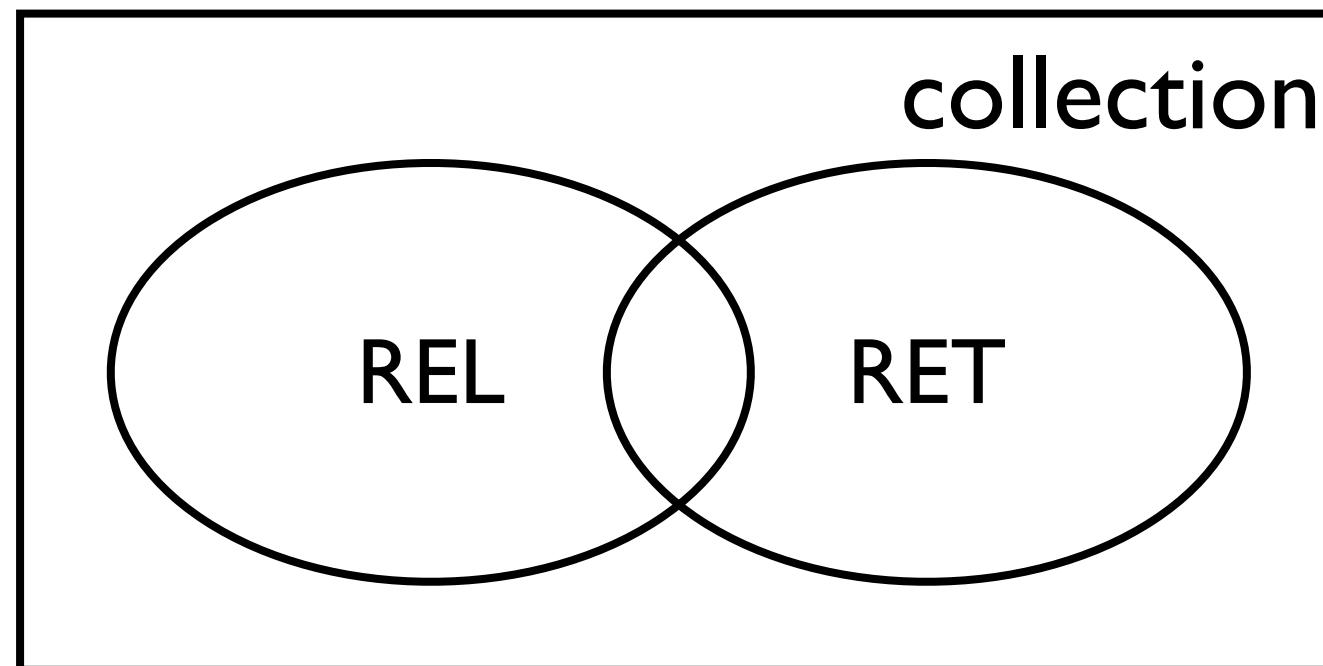
- So far, we've defined precision and recall assuming boolean retrieval: a set of relevant documents (REL) and a set of retrieved documents (RET)



Set Retrieval

precision and recall

- **Precision (P):** the proportion of retrieved documents that are relevant

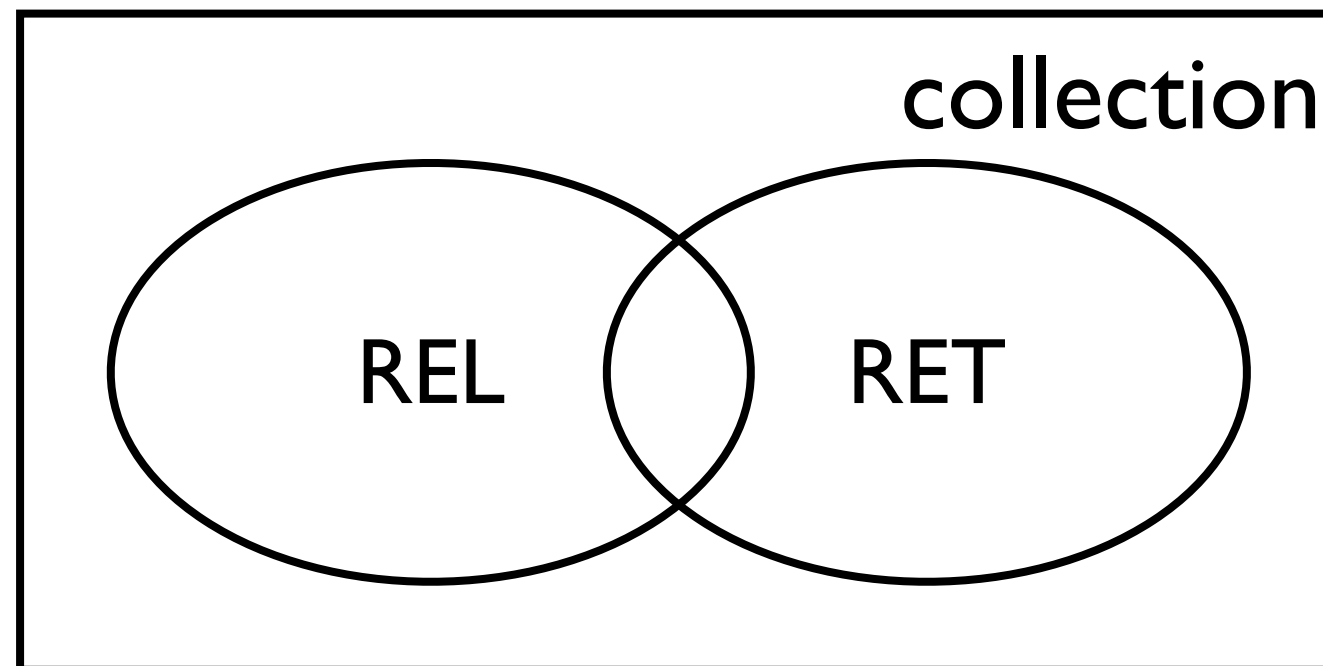


$$\mathcal{P} = \frac{|RET \cap REL|}{|RET|}$$

Set Retrieval

precision and recall

- **Recall (R):** the proportion of relevant documents that are retrieved



$$\mathcal{R} = \frac{|RET \cap REL|}{|REL|}$$

Set Retrieval

precision and recall

- Recall measures the system's ability to find all the relevant documents
- Precision measures the system's ability to reject any non-relevant documents in the retrieved set

Set Retrieval

precision and recall

- A system can make two types of errors:
 - a false positive error: the system retrieves a document that is non-relevant (should not have been retrieved)
 - a false negative error: the system fails to retrieve a document that is relevant (should have been retrieved)
- How do these types of errors affect precision and recall?

Set Retrieval

precision and recall

- A system can make two types of errors:
 - a false positive error: the system retrieves a document that is non-relevant (should not have been retrieved)
 - a false negative error: the system fails to retrieve a document that is relevant (should have been retrieved)
- How do these types of errors affect precision and recall?
- Precision is affected by the number of false positive errors
- Recall is affected by the number of false negative errors

Set Retrieval

combining precision and recall

- Oftentimes, we want a system that has high precision and high recall
- We want a metric that measures the balance between precision and recall
- One possibility would be to use the arithmetic mean:

$$\text{arithmetic mean}(\mathcal{P}, \mathcal{R}) = \frac{\mathcal{P} + \mathcal{R}}{2}$$

- What is problematic with this way of summarizing precision and recall?

Set Retrieval

combining precision and recall

- It's easy for a system to “game” the arithmetic mean of precision and recall
- **Bad:** a system that obtains **1.0** precision and near **0.0** recall would get a mean value of about **0.50**
- **Bad:** a system that obtains **1.0** recall and near **0.0** precision would get a mean value of about **0.50**
- **Better:** a system that obtains **0.50** precision and near **0.50** recall would get a mean value of about **0.50**

Set Retrieval

F-measure (also known as F1)

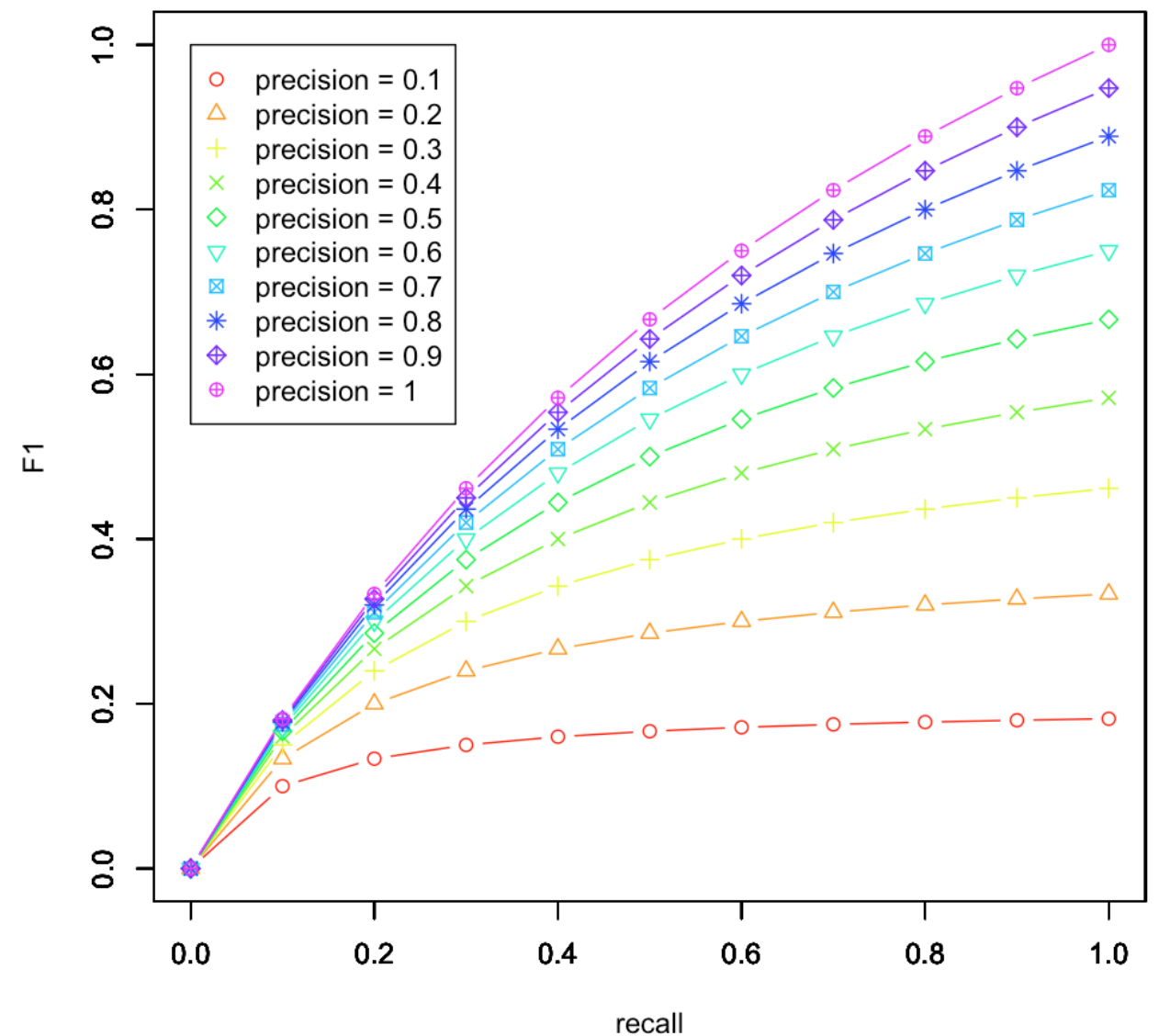
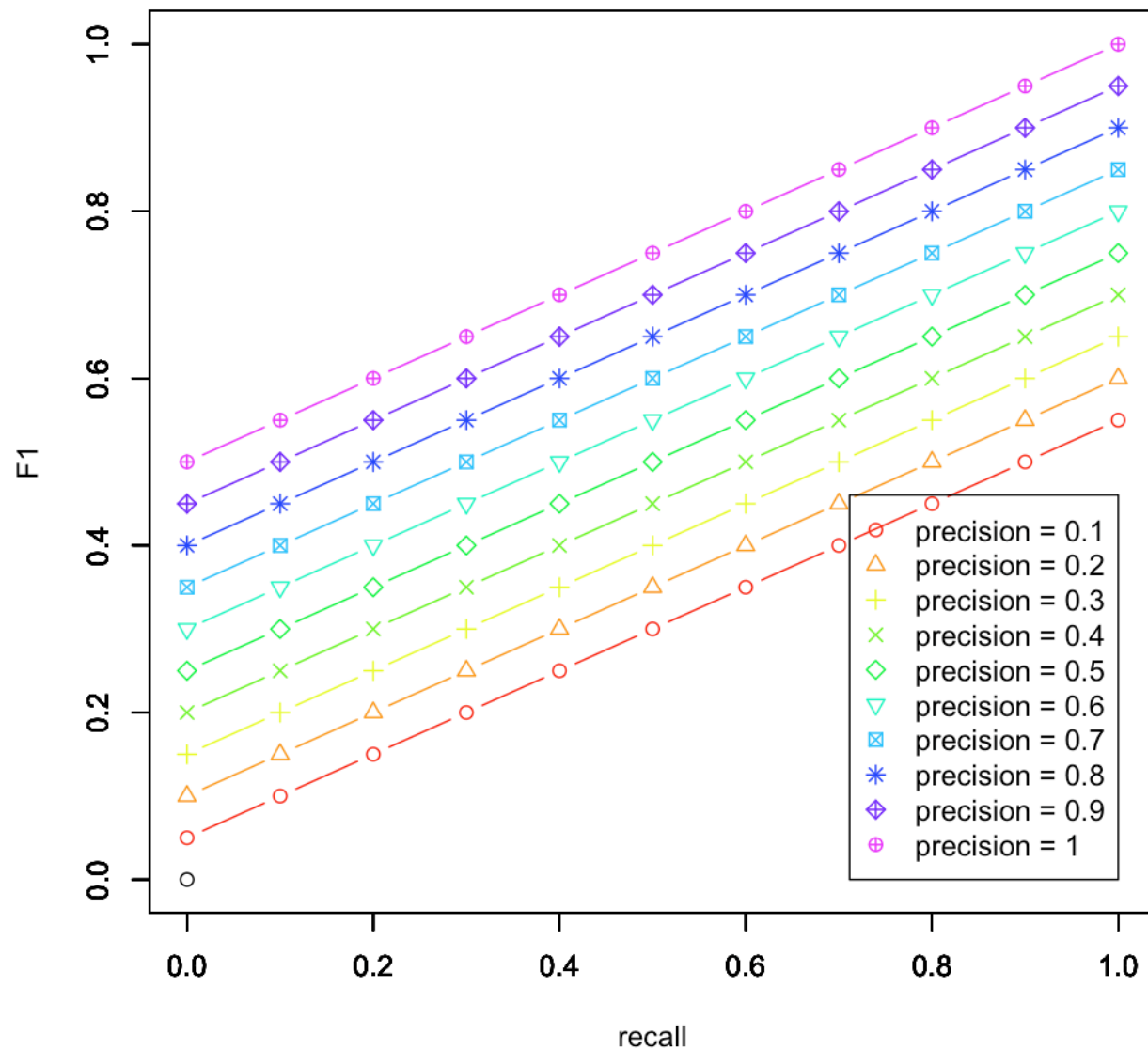
- A system that retrieves a single relevant document would get **1.0** precision and near **0.0** recall
- A system that retrieves the entire collection would get **1.0** recall and near **0.0** precision
- **Solution:** use the harmonic mean rather than the arithmetic mean
- **F-measure:**

$$\mathcal{F} = \frac{1}{\frac{1}{2} \left(\frac{1}{\mathcal{P}} + \frac{1}{\mathcal{R}} \right)} = \frac{2 \times \mathcal{P} \times \mathcal{R}}{\mathcal{P} + \mathcal{R}}$$

Set Retrieval

F-measure (also known as F1)

- The harmonic mean punishes small values



(slide courtesy of Ben Carterette)

Ranked Retrieval

precision and recall

- In most situations, the system outputs a ranked list of documents rather than an unordered set
- User-behavior assumption:
 - ▶ The user examines the output ranking from top-to-bottom until he/she is satisfied or gives up
- Precision and recall can also be used to evaluate a ranking
- Precision/Recall @ rank K

Ranked Retrieval

precision and recall

- **Precision:** proportion of retrieved documents that are relevant
- **Recall:** proportion of relevant documents that are retrieved



Ranked Retrieval

precision and recall

- $P@K$: proportion of retrieved top- K documents that are relevant
- $R@K$: proportion of relevant documents that are retrieved in the top- K
- **Assumption:** the user will only examine the top- K results



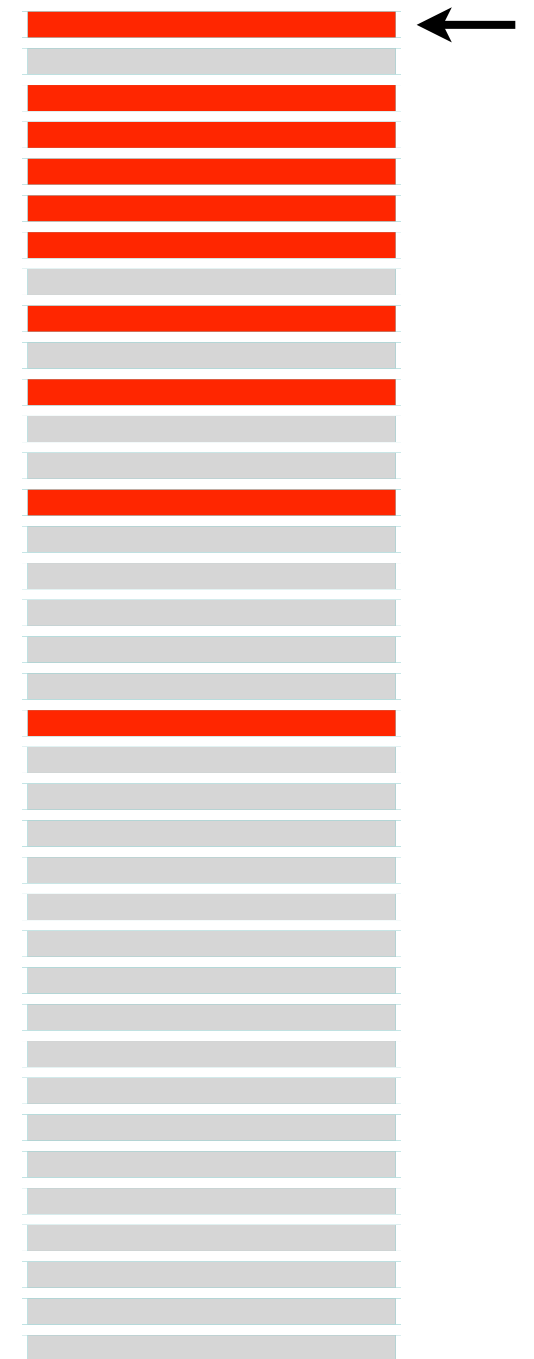
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|---------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

K = 1



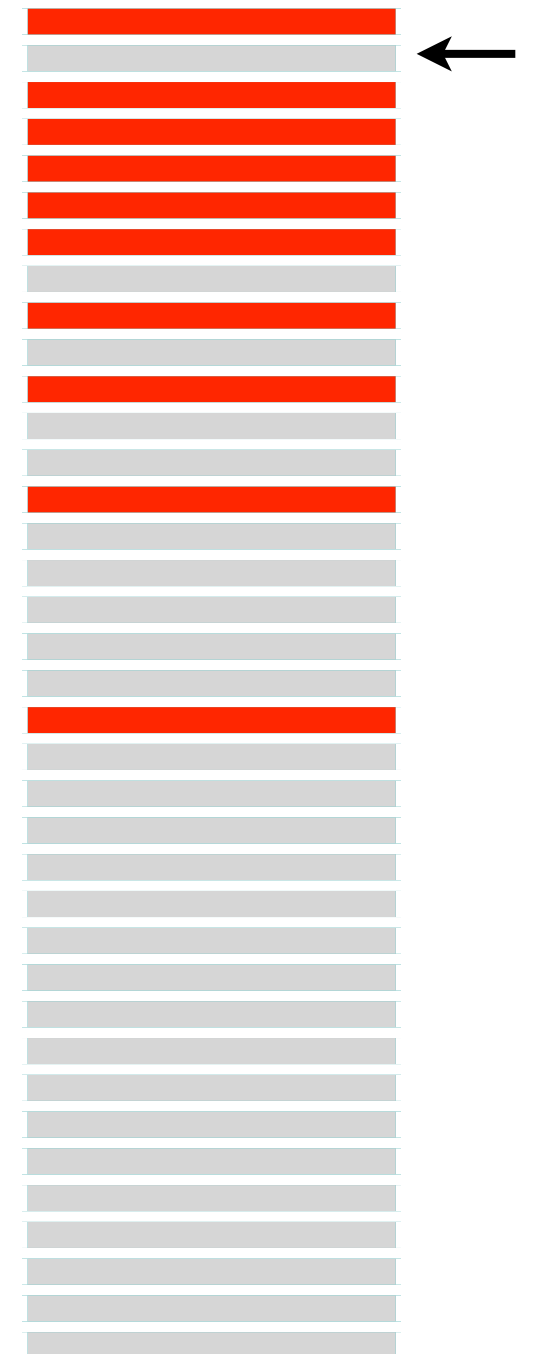
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|---------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | $(1/2) = 0.5$ | $(1/20) = 0.05$ |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

K = 2



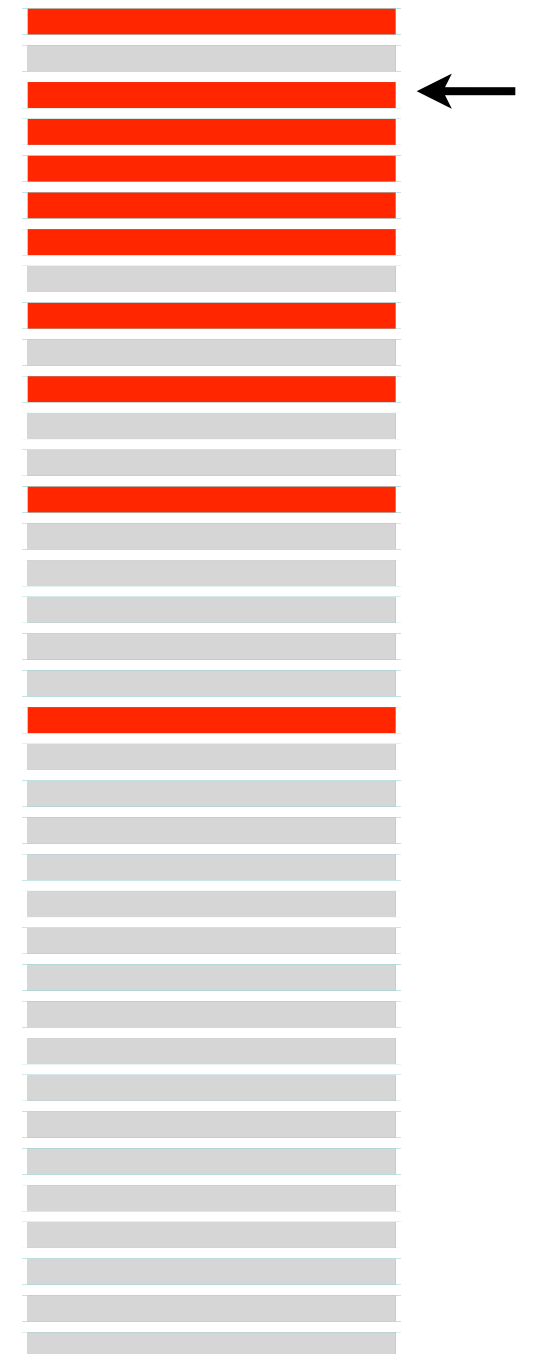
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|----------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | $(1/2) = 0.5$ | $(1/20) = 0.05$ |
| 3 | $(2/3) = 0.67$ | $(2/20) = 0.10$ |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

K = 3



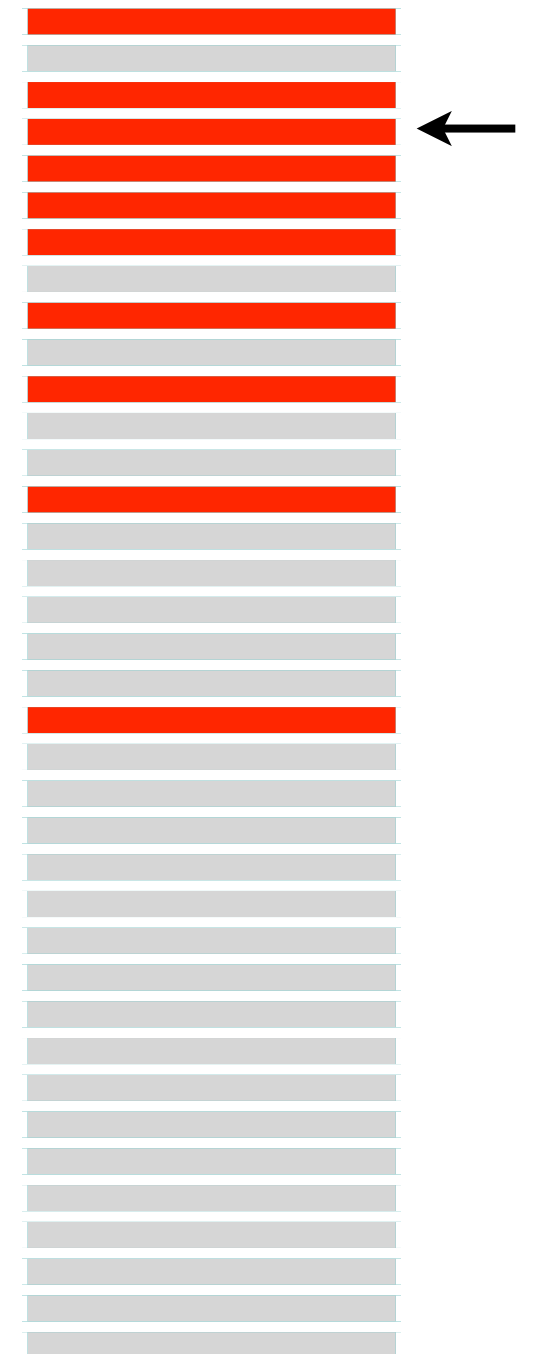
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|----------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | $(1/2) = 0.5$ | $(1/20) = 0.05$ |
| 3 | $(2/3) = 0.67$ | $(2/20) = 0.10$ |
| 4 | $(3/4) = 0.75$ | $(3/20) = 0.15$ |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

K = 4



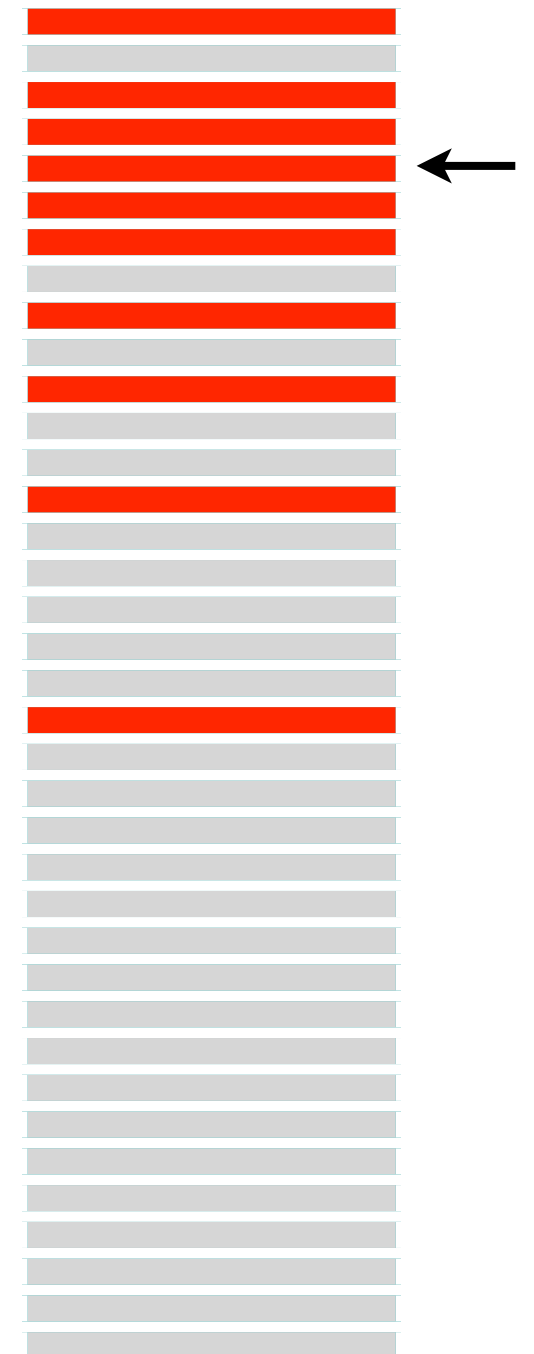
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|----------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | $(1/2) = 0.5$ | $(1/20) = 0.05$ |
| 3 | $(2/3) = 0.67$ | $(2/20) = 0.10$ |
| 4 | $(3/4) = 0.75$ | $(3/20) = 0.15$ |
| 5 | $(4/5) = 0.80$ | $(4/20) = 0.20$ |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

K = 5



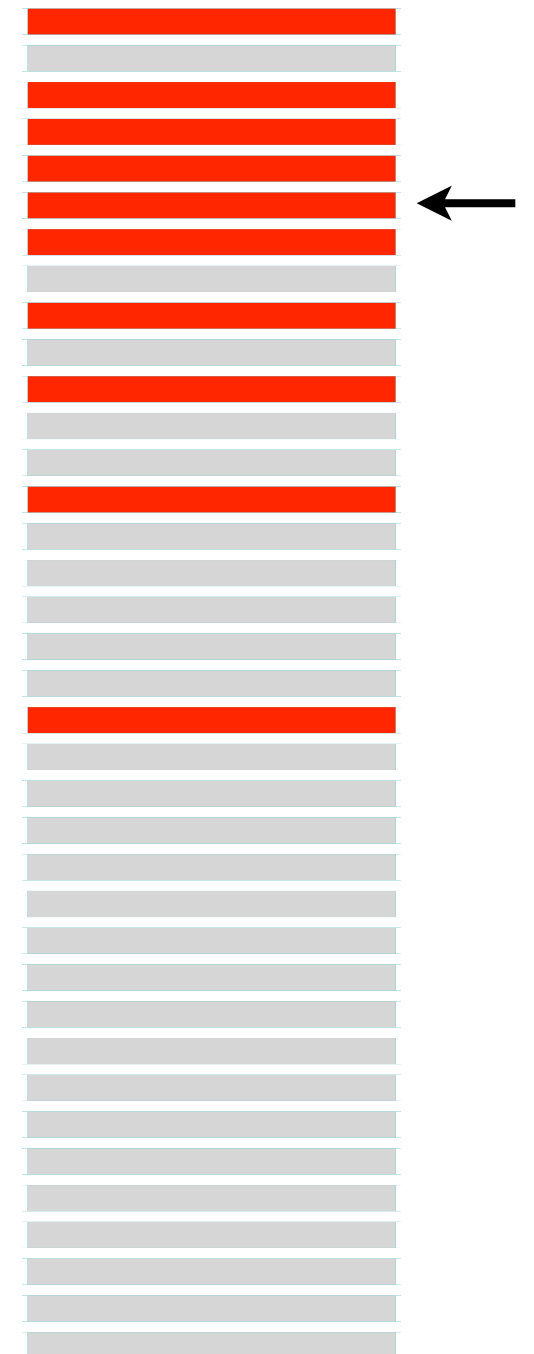
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|----------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | $(1/2) = 0.5$ | $(1/20) = 0.05$ |
| 3 | $(2/3) = 0.67$ | $(2/20) = 0.10$ |
| 4 | $(3/4) = 0.75$ | $(3/20) = 0.15$ |
| 5 | $(4/5) = 0.80$ | $(4/20) = 0.20$ |
| 6 | $(5/6) = 0.83$ | $(5/20) = 0.25$ |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

K = 6



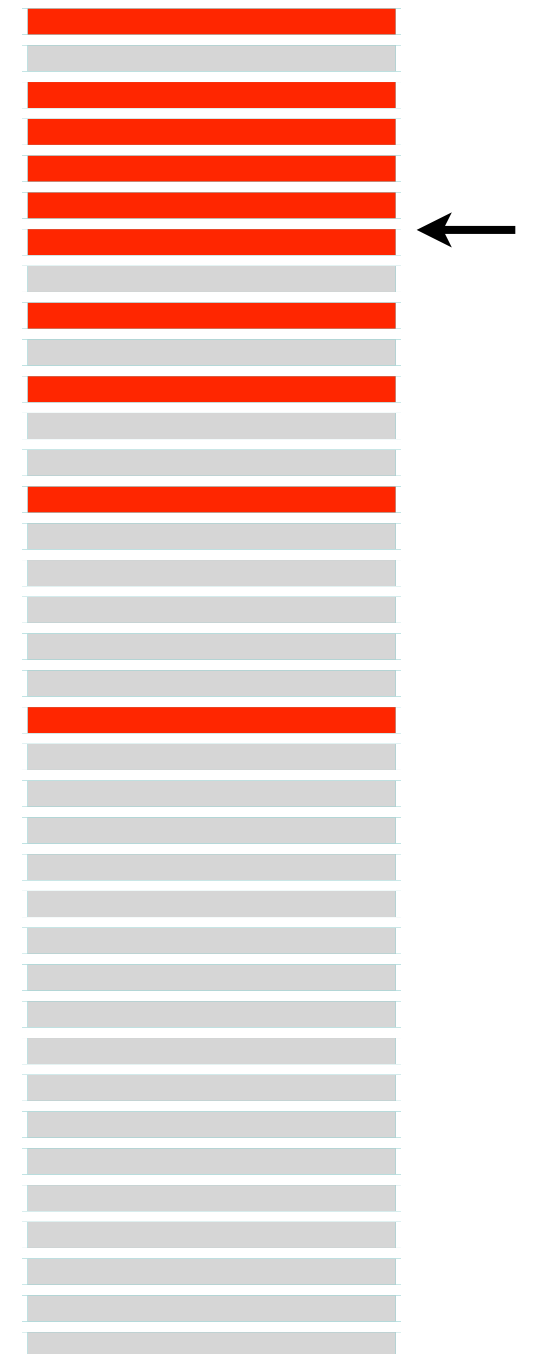
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|----------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | $(1/2) = 0.5$ | $(1/20) = 0.05$ |
| 3 | $(2/3) = 0.67$ | $(2/20) = 0.10$ |
| 4 | $(3/4) = 0.75$ | $(3/20) = 0.15$ |
| 5 | $(4/5) = 0.80$ | $(4/20) = 0.20$ |
| 6 | $(5/6) = 0.83$ | $(5/20) = 0.25$ |
| 7 | $(6/7) = 0.86$ | $(6/20) = 0.30$ |
| 8 | | |
| 9 | | |
| 10 | | |

K = 7



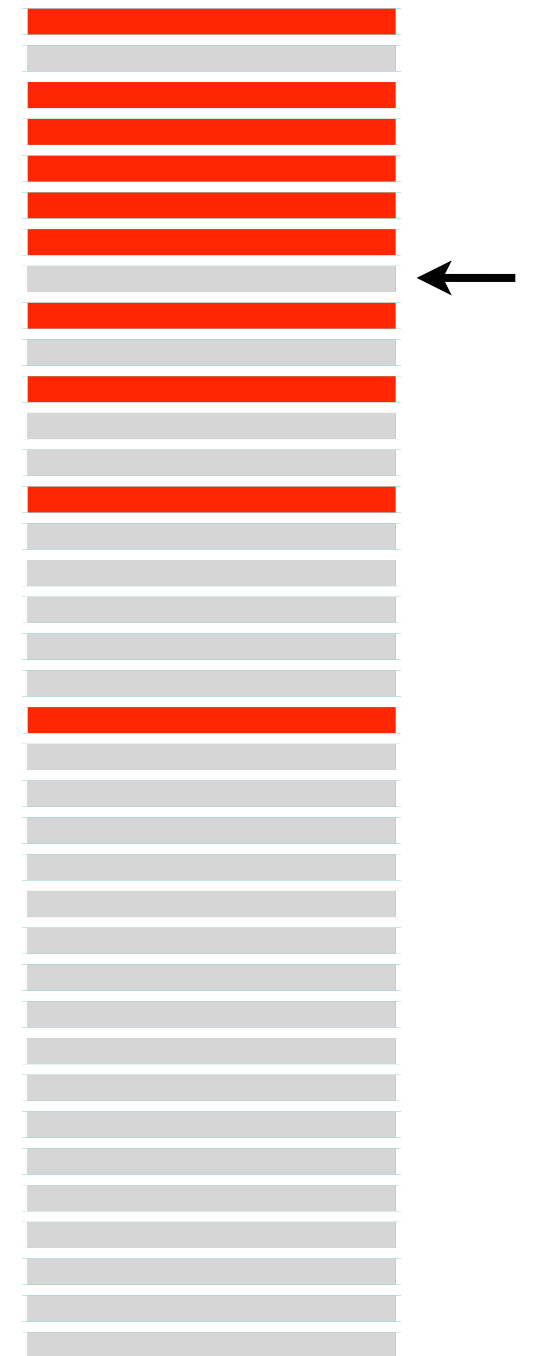
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|----------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | $(1/2) = 0.5$ | $(1/20) = 0.05$ |
| 3 | $(2/3) = 0.67$ | $(2/20) = 0.10$ |
| 4 | $(3/4) = 0.75$ | $(3/20) = 0.15$ |
| 5 | $(4/5) = 0.80$ | $(4/20) = 0.20$ |
| 6 | $(5/6) = 0.83$ | $(5/20) = 0.25$ |
| 7 | $(6/7) = 0.86$ | $(6/20) = 0.30$ |
| 8 | $(6/8) = 0.75$ | $(6/20) = 0.30$ |
| 9 | | |
| 10 | | |

K = 8



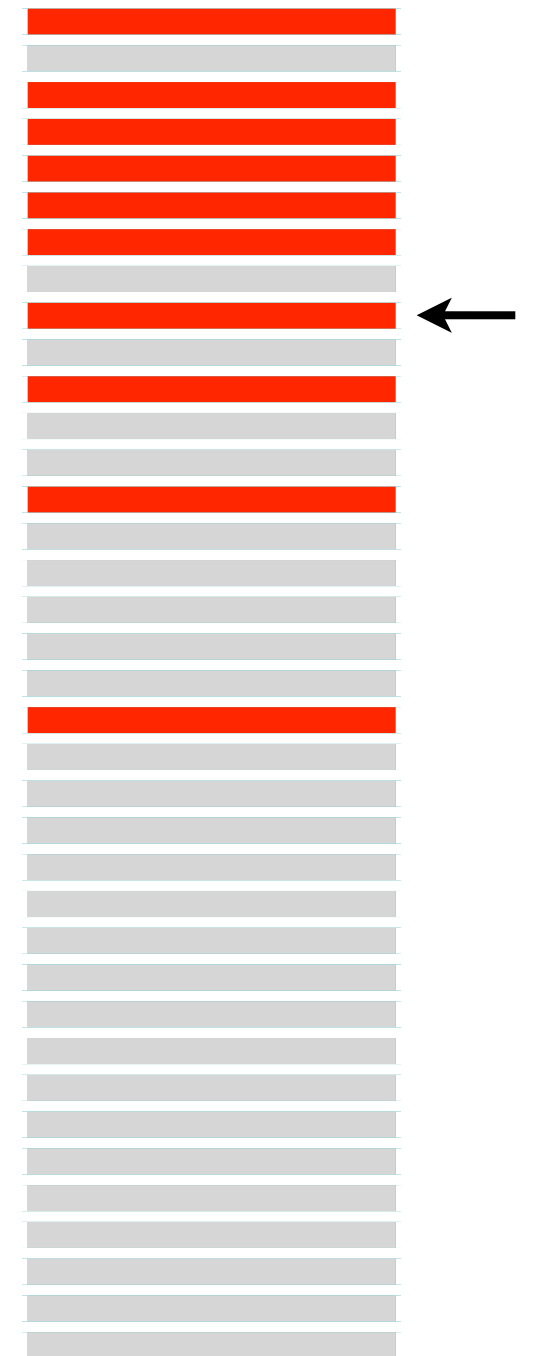
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|----------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | $(1/2) = 0.5$ | $(1/20) = 0.05$ |
| 3 | $(2/3) = 0.67$ | $(2/20) = 0.10$ |
| 4 | $(3/4) = 0.75$ | $(3/20) = 0.15$ |
| 5 | $(4/5) = 0.80$ | $(4/20) = 0.20$ |
| 6 | $(5/6) = 0.83$ | $(5/20) = 0.25$ |
| 7 | $(6/7) = 0.86$ | $(6/20) = 0.30$ |
| 8 | $(6/8) = 0.75$ | $(6/20) = 0.30$ |
| 9 | $(7/9) = 0.78$ | $(7/20) = 0.35$ |
| 10 | | |

K = 9



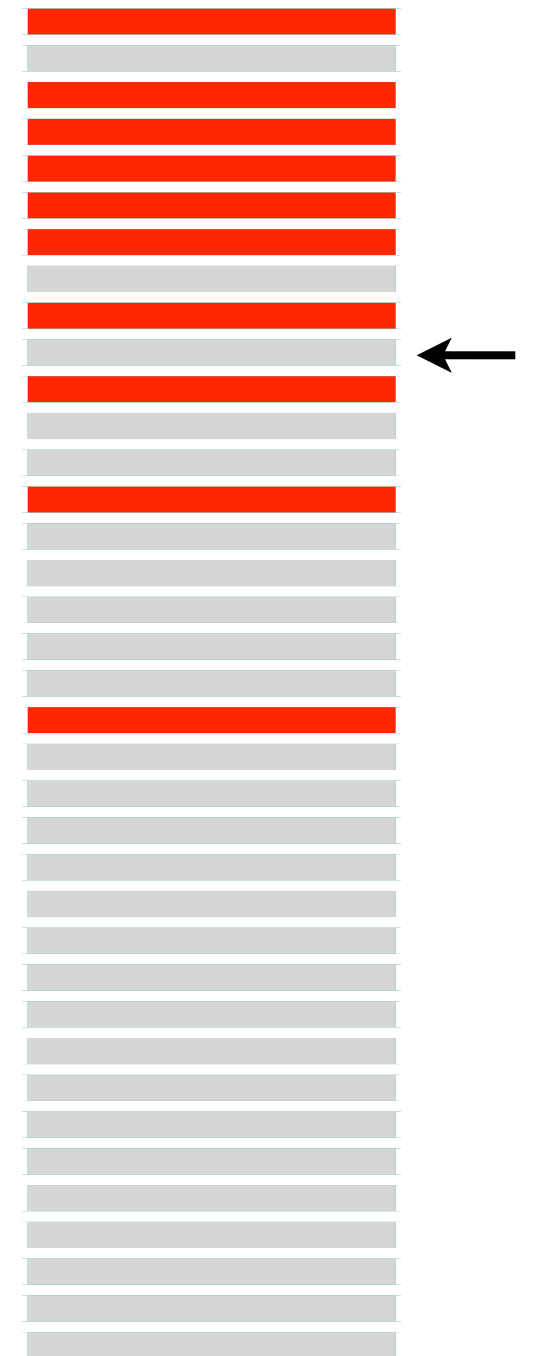
Ranked Retrieval

precision and recall: exercise

- Assume 20 **relevant** documents

| K | P@K | R@K |
|----|-----------------|-----------------|
| 1 | $(1/1) = 1.0$ | $(1/20) = 0.05$ |
| 2 | $(1/2) = 0.5$ | $(1/20) = 0.05$ |
| 3 | $(2/3) = 0.67$ | $(2/20) = 0.10$ |
| 4 | $(3/4) = 0.75$ | $(3/20) = 0.15$ |
| 5 | $(4/5) = 0.80$ | $(4/20) = 0.20$ |
| 6 | $(5/6) = 0.83$ | $(5/20) = 0.25$ |
| 7 | $(6/7) = 0.86$ | $(6/20) = 0.30$ |
| 8 | $(6/8) = 0.75$ | $(6/20) = 0.30$ |
| 9 | $(7/9) = 0.78$ | $(7/20) = 0.35$ |
| 10 | $(7/10) = 0.70$ | $(7/20) = 0.35$ |

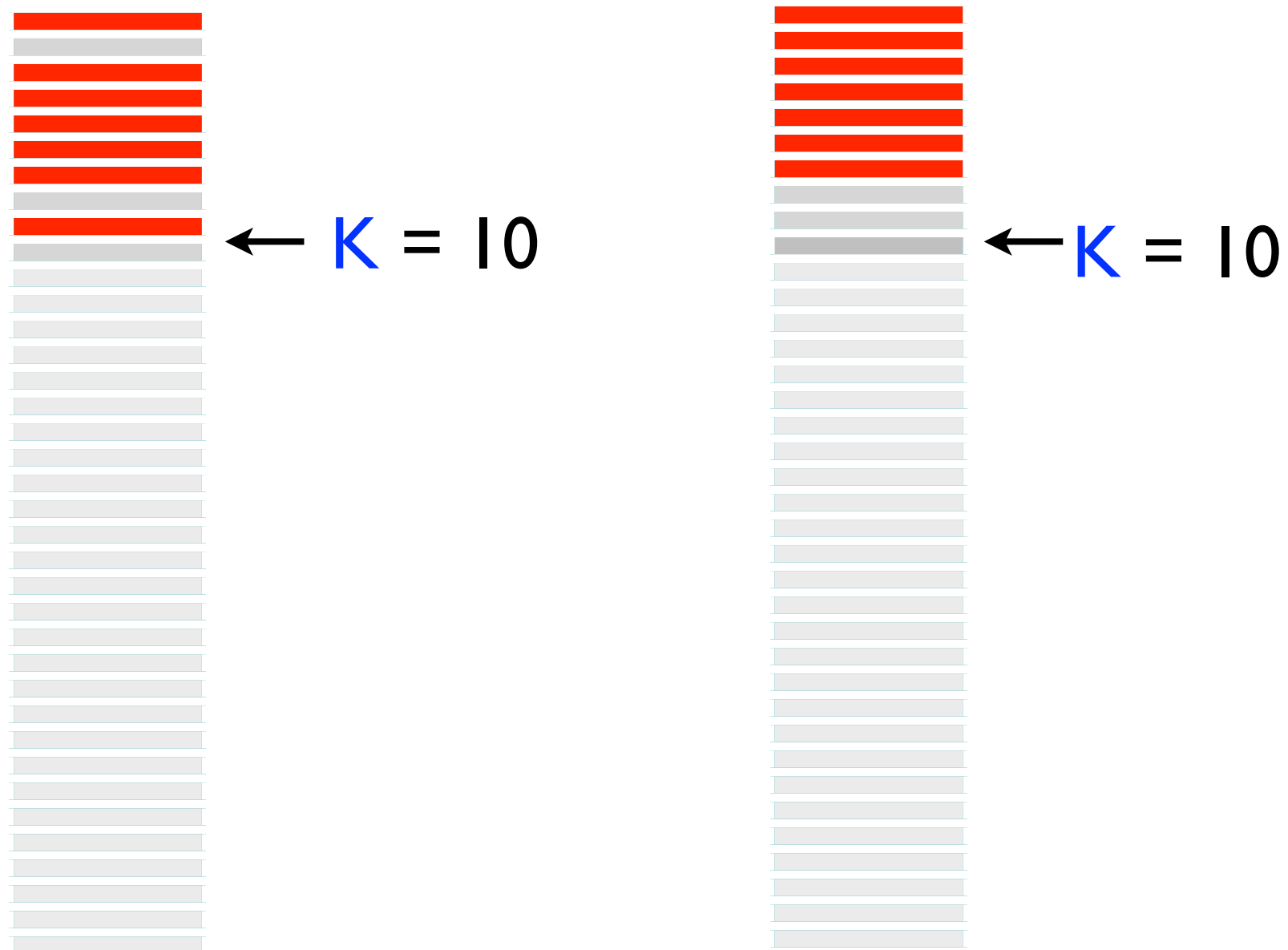
K = 10



Ranked Retrieval

precision and recall

- **Problem:** what value of **K** should we use to evaluate?
- Which is better in terms of **P@10** and **R@10**?



Ranked Retrieval

precision and recall

- The ranking of documents within the top K is inconsequential
- If we don't know what value of K to choose, we can compute and report several: $P/R@\{1,5,10,20\}$
- There are evaluation metrics that do not require choosing K (as we will see)
- One advantage of $P/R@K$, however, is that they are easy to interpret

Ranked Retrieval

what do these statements mean?

- As with most metrics, experimenters report average values (averaged across evaluation queries)
- System **A** obtains an average **P@10** of 0.50
- System **A** obtains an average **P@10** of 0.10
- System **A** obtains an average **P@1** of 0.50
- System **A** obtains an average **P@20** of 0.20

Ranked Retrieval

comparing systems

- **Good practice:** always ask yourself “Are users likely to notice?”
- System **A** obtains an average **P@I** of 0.10
- System **B** obtains an average **P@I** of 0.20
- This is a 100% improvement.
- Are user’s likely to notice?

Ranked Retrieval

comparing systems

- **Good practice:** always ask yourself “Are users likely to notice?”
- System **A** obtains an average **P@I** of 0.05
- System **B** obtains an average **P@I** of 0.10
- This is a 100% improvement.
- Are user’s likely to notice?

Ranked Retrieval

P/R@K

- Advantages:
 - ▶ easy to compute
 - ▶ easy to interpret
- Disadvantages:
 - ▶ the value of **K** has a huge impact on the metric
 - ▶ the ranking above **K** is inconsequential
 - ▶ how do we pick **K**?

Ranked Retrieval

motivation: average precision

- Ideally, we want the system to achieve high precision for varying values of K
- The metric *average precision* accounts for precision and recall without having to set K

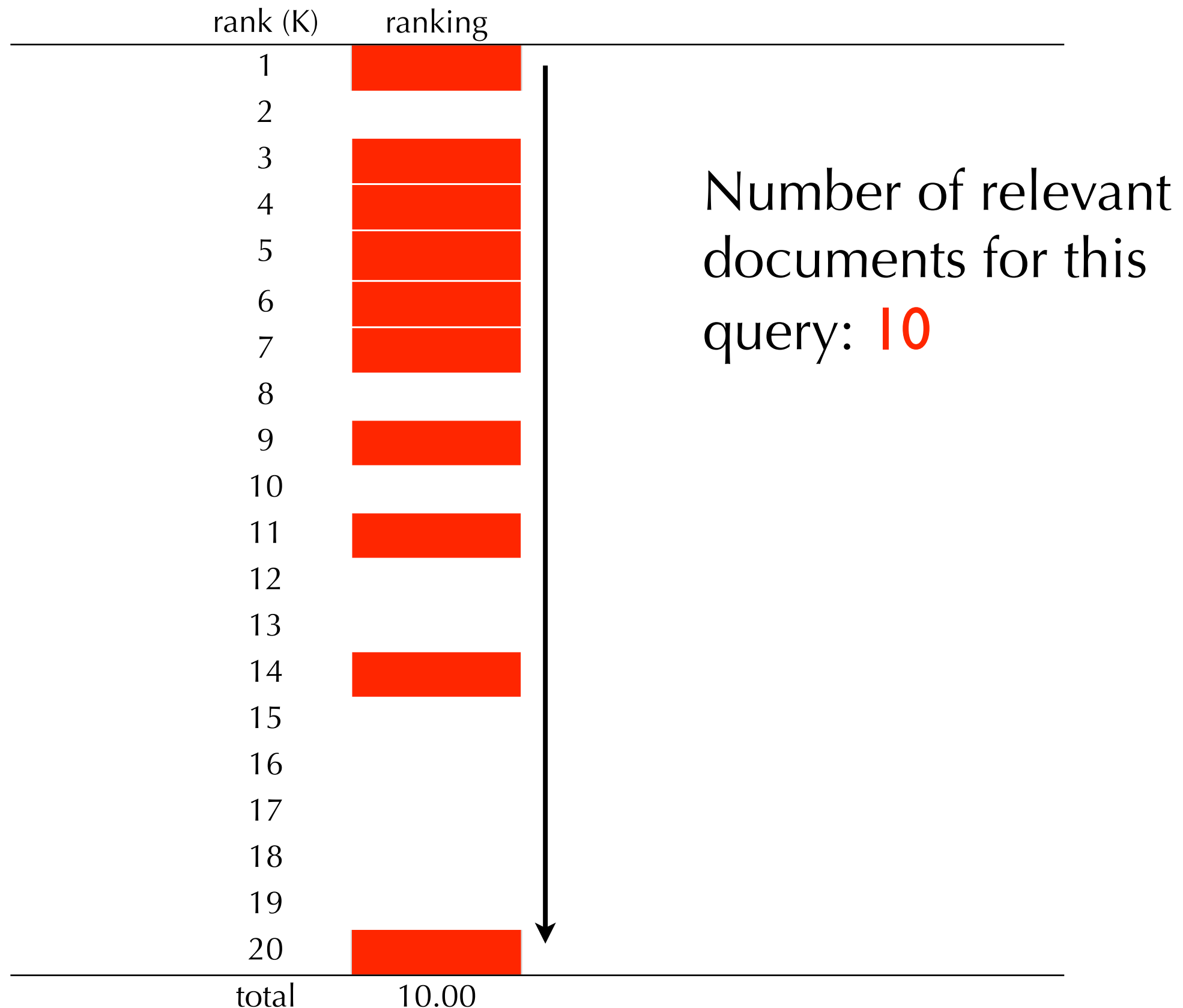
Ranked Retrieval

average precision

1. Go down the ranking one-rank-at-a-time
2. If the document at rank K is relevant, measure $P@K$
 - ▶ proportion of top- K documents that are relevant
3. Finally, take the average of all $P@K$ values
 - ▶ the number of $P@K$ values will equal the number of relevant documents

Ranked Retrieval

average-precision



Ranked Retrieval

average-precision

| rank (K) | ranking |
|----------|---------|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| 11 | |
| 12 | |
| 13 | |
| 14 | |
| 15 | |
| 16 | |
| 17 | |
| 18 | |
| 19 | |
| 20 | |
| total | 10.00 |

1. Go down the ranking one-rank-at-a-time
2. If recall goes up, calculate $P@K$ at that rank K
3. When recall = 1.0, average $P@K$ values

Ranked Retrieval

average-precision

| rank (K) | ranking | R@K | P@K |
|----------|---------|-------------------|------|
| 1 | | 0.10 | 1.00 |
| 2 | | 0.10 | 0.50 |
| 3 | | 0.20 | 0.67 |
| 4 | | 0.30 | 0.75 |
| 5 | | 0.40 | 0.80 |
| 6 | | 0.50 | 0.83 |
| 7 | | 0.60 | 0.86 |
| 8 | | 0.60 | 0.75 |
| 9 | | 0.70 | 0.78 |
| 10 | | 0.70 | 0.70 |
| 11 | | 0.80 | 0.73 |
| 12 | | 0.80 | 0.67 |
| 13 | | 0.80 | 0.62 |
| 14 | | 0.90 | 0.64 |
| 15 | | 0.90 | 0.60 |
| 16 | | 0.90 | 0.56 |
| 17 | | 0.90 | 0.53 |
| 18 | | 0.90 | 0.50 |
| 19 | | 0.90 | 0.47 |
| 20 | | 1.00 | 0.50 |
| total | 10.00 | average-precision | 0.76 |

Ranked Retrieval

average-precision

| rank (K) | ranking | R@K | P@K |
|----------|---------|-------|------------------------|
| 1 | | 0.10 | 1.00 |
| 2 | | 0.20 | 1.00 |
| 3 | | 0.30 | 1.00 |
| 4 | | 0.40 | 1.00 |
| 5 | | 0.50 | 1.00 |
| 6 | | 0.60 | 1.00 |
| 7 | | 0.70 | 1.00 |
| 8 | | 0.80 | 1.00 |
| 9 | | 0.90 | 1.00 |
| 10 | | 1.00 | 1.00 |
| 11 | | 1.00 | 0.91 |
| 12 | | 1.00 | 0.83 |
| 13 | | 1.00 | 0.77 |
| 14 | | 1.00 | 0.71 |
| 15 | | 1.00 | 0.67 |
| 16 | | 1.00 | 0.63 |
| 17 | | 1.00 | 0.59 |
| 18 | | 1.00 | 0.56 |
| 19 | | 1.00 | 0.53 |
| 20 | | 1.00 | 0.50 |
| total | | 10.00 | average-precision 1.00 |

Ranked Retrieval

average-precision

| rank (K) | ranking | R@K | P@K |
|----------|---------|-------|------------------------|
| 1 | | 0.00 | 0.00 |
| 2 | | 0.00 | 0.00 |
| 3 | | 0.00 | 0.00 |
| 4 | | 0.00 | 0.00 |
| 5 | | 0.00 | 0.00 |
| 6 | | 0.00 | 0.00 |
| 7 | | 0.00 | 0.00 |
| 8 | | 0.00 | 0.00 |
| 9 | | 0.00 | 0.00 |
| 10 | | 0.00 | 0.00 |
| 11 | | 0.10 | 0.09 |
| 12 | | 0.20 | 0.17 |
| 13 | | 0.30 | 0.23 |
| 14 | | 0.40 | 0.29 |
| 15 | | 0.50 | 0.33 |
| 16 | | 0.60 | 0.38 |
| 17 | | 0.70 | 0.41 |
| 18 | | 0.80 | 0.44 |
| 19 | | 0.90 | 0.47 |
| 20 | | 1.00 | 0.50 |
| total | | 10.00 | average-precision 0.33 |

Ranked Retrieval

average-precision

| rank (K) | ranking | R@K | P@K |
|----------|---------|-------|------------------------|
| 1 | | 0.10 | 1.00 |
| 2 | | 0.10 | 0.50 |
| 3 | | 0.20 | 0.67 |
| 4 | | 0.30 | 0.75 |
| 5 | | 0.40 | 0.80 |
| 6 | | 0.50 | 0.83 |
| 7 | | 0.60 | 0.86 |
| 8 | | 0.60 | 0.75 |
| 9 | | 0.70 | 0.78 |
| 10 | | 0.70 | 0.70 |
| 11 | | 0.80 | 0.73 |
| 12 | | 0.80 | 0.67 |
| 13 | | 0.80 | 0.62 |
| 14 | | 0.90 | 0.64 |
| 15 | | 0.90 | 0.60 |
| 16 | | 0.90 | 0.56 |
| 17 | | 0.90 | 0.53 |
| 18 | | 0.90 | 0.50 |
| 19 | | 0.90 | 0.47 |
| 20 | | 1.00 | 0.50 |
| total | | 10.00 | average-precision 0.76 |

Ranked Retrieval

average-precision

swapped
ranks 2 and 3

| rank (K) | ranking | R@K | P@K |
|----------|---------|-------|------|
| 1 | | 0.10 | 1.00 |
| 2 | | 0.20 | 1.00 |
| 3 | | 0.20 | 0.67 |
| 4 | | 0.30 | 0.75 |
| 5 | | 0.40 | 0.80 |
| 6 | | 0.50 | 0.83 |
| 7 | | 0.60 | 0.86 |
| 8 | | 0.60 | 0.75 |
| 9 | | 0.70 | 0.78 |
| 10 | | 0.70 | 0.70 |
| 11 | | 0.80 | 0.73 |
| 12 | | 0.80 | 0.67 |
| 13 | | 0.80 | 0.62 |
| 14 | | 0.90 | 0.64 |
| 15 | | 0.90 | 0.60 |
| 16 | | 0.90 | 0.56 |
| 17 | | 0.90 | 0.53 |
| 18 | | 0.90 | 0.50 |
| 19 | | 0.90 | 0.47 |
| 20 | | 1.00 | 0.50 |
| total | | 10.00 | 0.79 |

Ranked Retrieval

average-precision

| rank (K) | ranking | R@K | P@K |
|----------|---------|-------------------|------|
| 1 | | 0.10 | 1.00 |
| 2 | | 0.10 | 0.50 |
| 3 | | 0.20 | 0.67 |
| 4 | | 0.30 | 0.75 |
| 5 | | 0.40 | 0.80 |
| 6 | | 0.50 | 0.83 |
| 7 | | 0.60 | 0.86 |
| 8 | | 0.60 | 0.75 |
| 9 | | 0.70 | 0.78 |
| 10 | | 0.70 | 0.70 |
| 11 | | 0.80 | 0.73 |
| 12 | | 0.80 | 0.67 |
| 13 | | 0.80 | 0.62 |
| 14 | | 0.90 | 0.64 |
| 15 | | 0.90 | 0.60 |
| 16 | | 0.90 | 0.56 |
| 17 | | 0.90 | 0.53 |
| 18 | | 0.90 | 0.50 |
| 19 | | 0.90 | 0.47 |
| 20 | | 1.00 | 0.50 |
| total | 10.00 | average-precision | 0.76 |

Ranked Retrieval

average-precision

swapped ranks
8 and 9

| rank (K) | ranking | R@K | P@K |
|----------|---------|-------------------|------|
| 1 | | 0.10 | 1.00 |
| 2 | | 0.10 | 0.50 |
| 3 | | 0.20 | 0.67 |
| 4 | | 0.30 | 0.75 |
| 5 | | 0.40 | 0.80 |
| 6 | | 0.50 | 0.83 |
| 7 | | 0.60 | 0.86 |
| 8 | | 0.70 | 0.88 |
| 9 | | 0.70 | 0.78 |
| 10 | | 0.70 | 0.70 |
| 11 | | 0.80 | 0.73 |
| 12 | | 0.80 | 0.67 |
| 13 | | 0.80 | 0.62 |
| 14 | | 0.90 | 0.64 |
| 15 | | 0.90 | 0.60 |
| 16 | | 0.90 | 0.56 |
| 17 | | 0.90 | 0.53 |
| 18 | | 0.90 | 0.50 |
| 19 | | 0.90 | 0.47 |
| 20 | | 1.00 | 0.50 |
| total | 10.00 | average-precision | 0.77 |

Ranked Retrieval

average precision

- Advantages:
 - ▶ no need to choose K
 - ▶ accounts for both precision and recall
 - ▶ ranking mistakes at the top of the ranking are more influential
 - ▶ ranking mistakes at the bottom of the ranking are still accounted for
- Disadvantages
 - ▶ not quite as easy to interpret as $P/R@K$

Ranked Retrieval

MAP: mean average precision

- So far, we've talked about average precision for a single query
- **Mean Average Precision (MAP):** average precision averaged across a set of queries
 - ▶ yes, confusing. but, better than calling it “average average precision”!
 - ▶ one of the most common metrics in IR evaluation

Ranked Retrieval

precision-recall curves

- In some situations, we want to understand the trade-off between precision and recall
- A precision-recall (PR) curve expresses precision as a function of recall

Ranked Retrieval

precision-recall curves: general idea

- Different tasks require different levels of recall
- Sometimes, the user wants a few relevant documents
- Other times, the user wants most of them
- Suppose a user wants some level of recall R
- The goal for the system is to minimize the number of false negatives the user must look at in order to achieve a level of recall R

Ranked Retrieval

precision-recall curves: general idea

- **False negative error:** not retrieving a relevant document
 - ▶ false negative errors affects recall
- **False positive errors:** retrieving a non-relevant document
 - ▶ false positives errors affects precision
- If a user wants to avoid a certain level of false-negatives, what is the level of false-positives he/she must filter through?

Ranked Retrieval

precision-recall curves



- Assume 10 relevant documents for this query
- Suppose the user wants $R = (1/10)$
- What level of precision will the user observe?

Ranked Retrieval

precision-recall curves



- Assume 10 relevant documents for this query
- Suppose the user wants $R = (2/10)$
- What level of precision will the user observe?

Ranked Retrieval











precision-recall curves



- Assume 10 relevant documents for this query
- Suppose the user wants $R = (10/10)$
- What level of precision will the user observe?

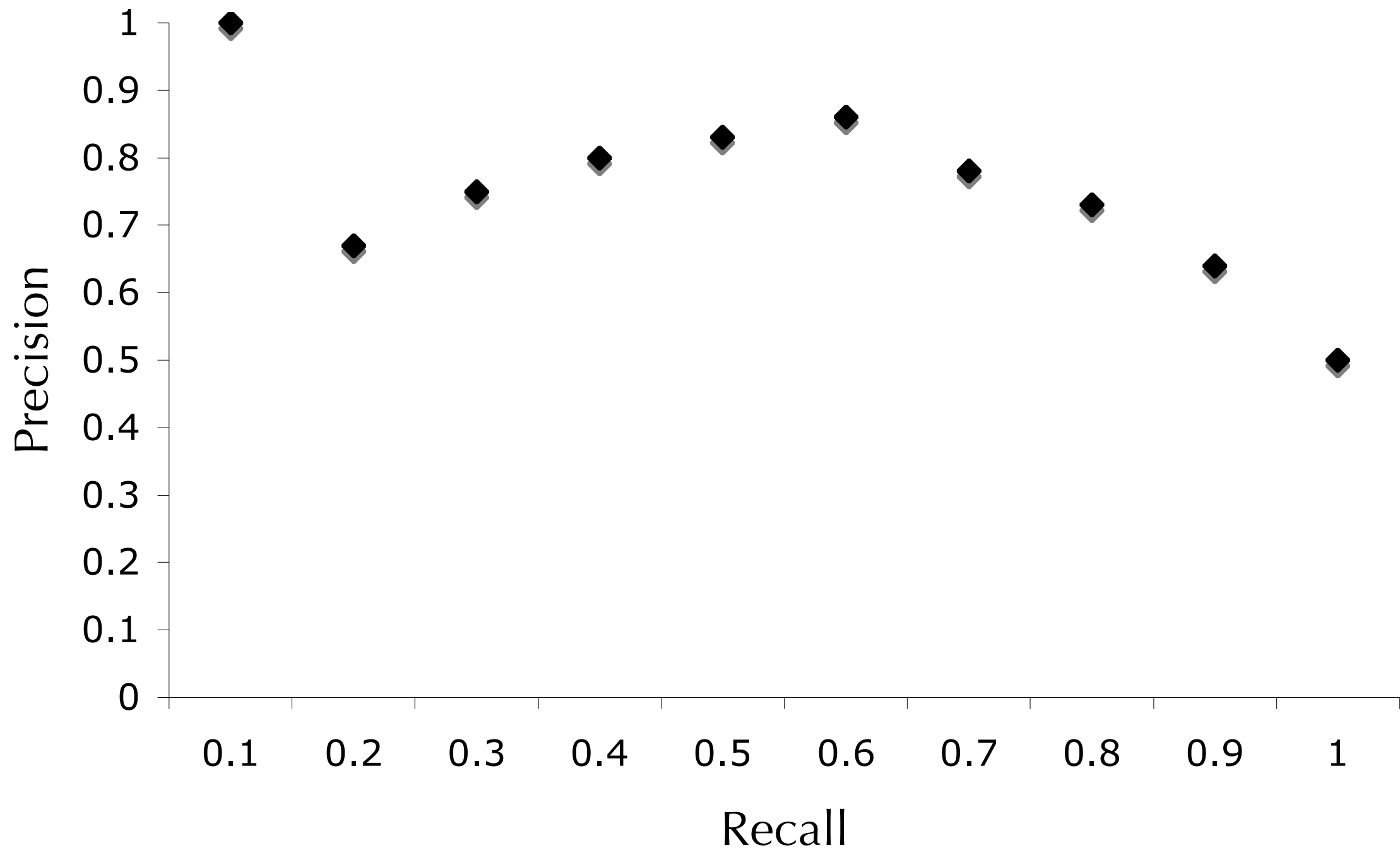
Ranked Retrieval

precision-recall curves

| rank (K) | ranking | R@K | P@K |
|----------|---|------|------|
| 1 |  | 0.10 | 1.00 |
| 2 | | 0.10 | 0.50 |
| 3 |  | 0.20 | 0.67 |
| 4 |  | 0.30 | 0.75 |
| 5 |  | 0.40 | 0.80 |
| 6 |  | 0.50 | 0.83 |
| 7 |  | 0.60 | 0.86 |
| 8 | | 0.60 | 0.75 |
| 9 |  | 0.70 | 0.78 |
| 10 | | 0.70 | 0.70 |
| 11 |  | 0.80 | 0.73 |
| 12 | | 0.80 | 0.67 |
| 13 | | 0.80 | 0.62 |
| 14 |  | 0.90 | 0.64 |
| 15 | | 0.90 | 0.60 |
| 16 | | 0.90 | 0.56 |
| 17 | | 0.90 | 0.53 |
| 18 | | 0.90 | 0.50 |
| 19 | | 0.90 | 0.47 |
| 20 |  | 1.00 | 0.50 |

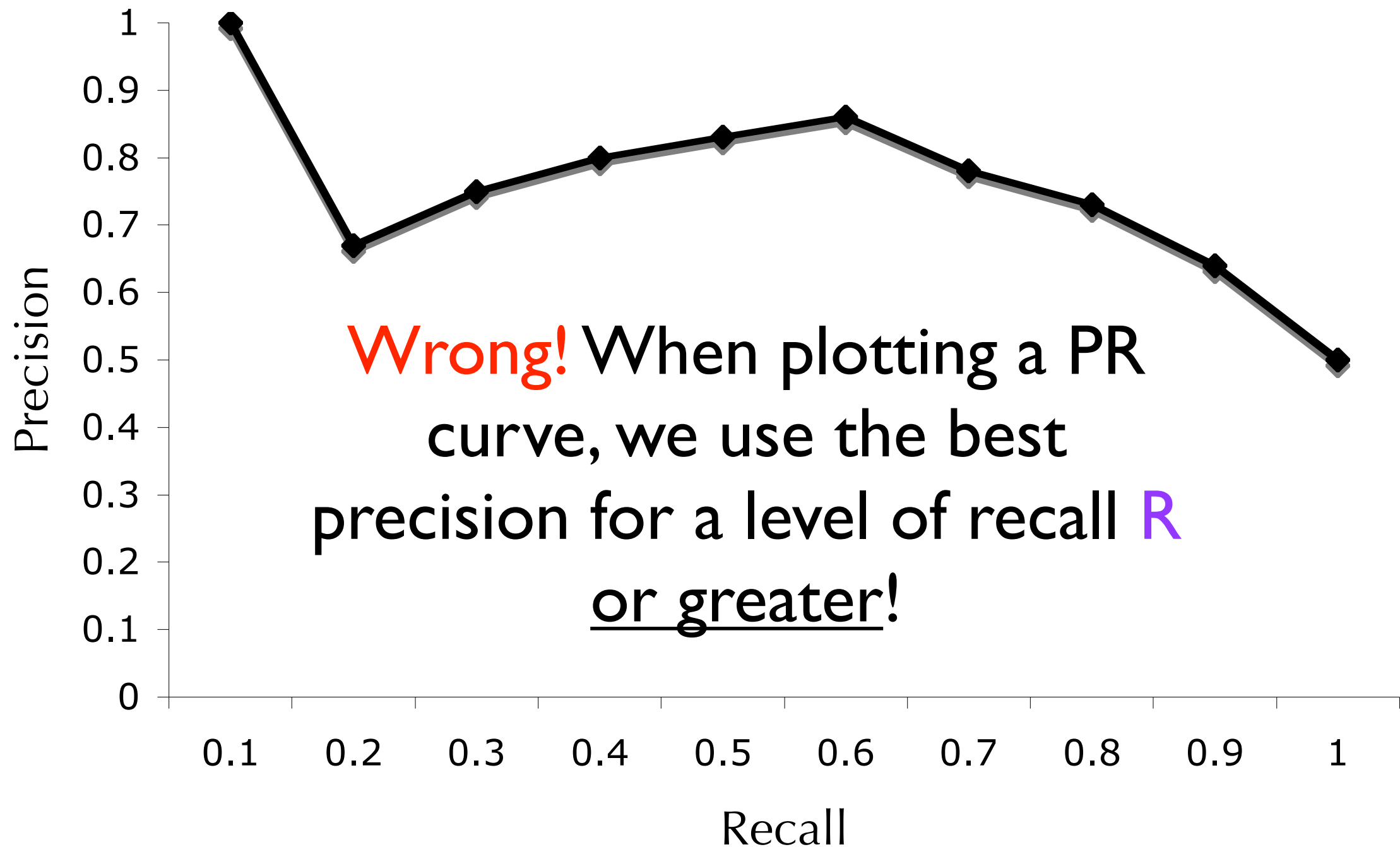
Ranked Retrieval

precision-recall curves



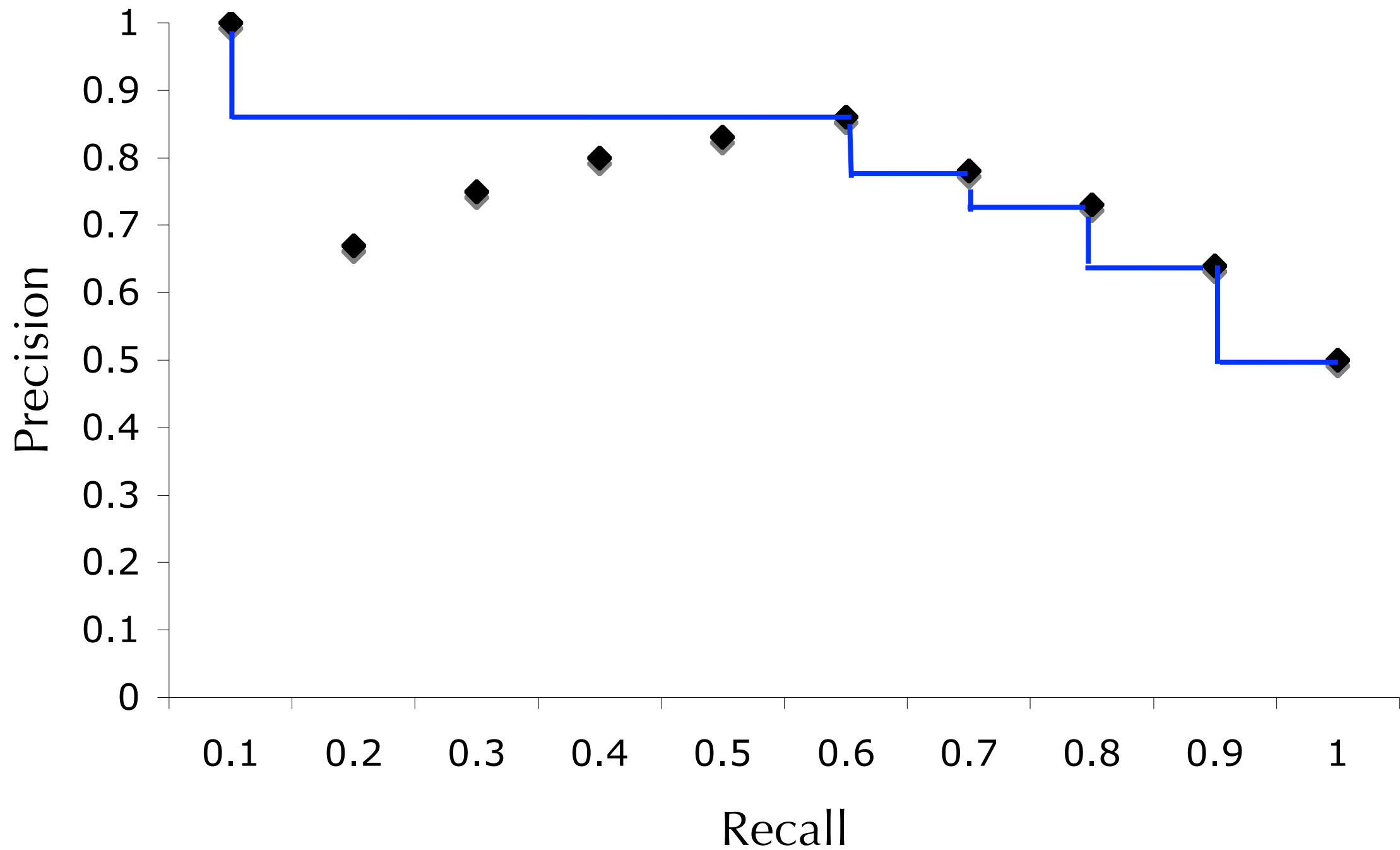
Ranked Retrieval

precision-recall curves



Ranked Retrieval

precision-recall curves



Ranked Retrieval

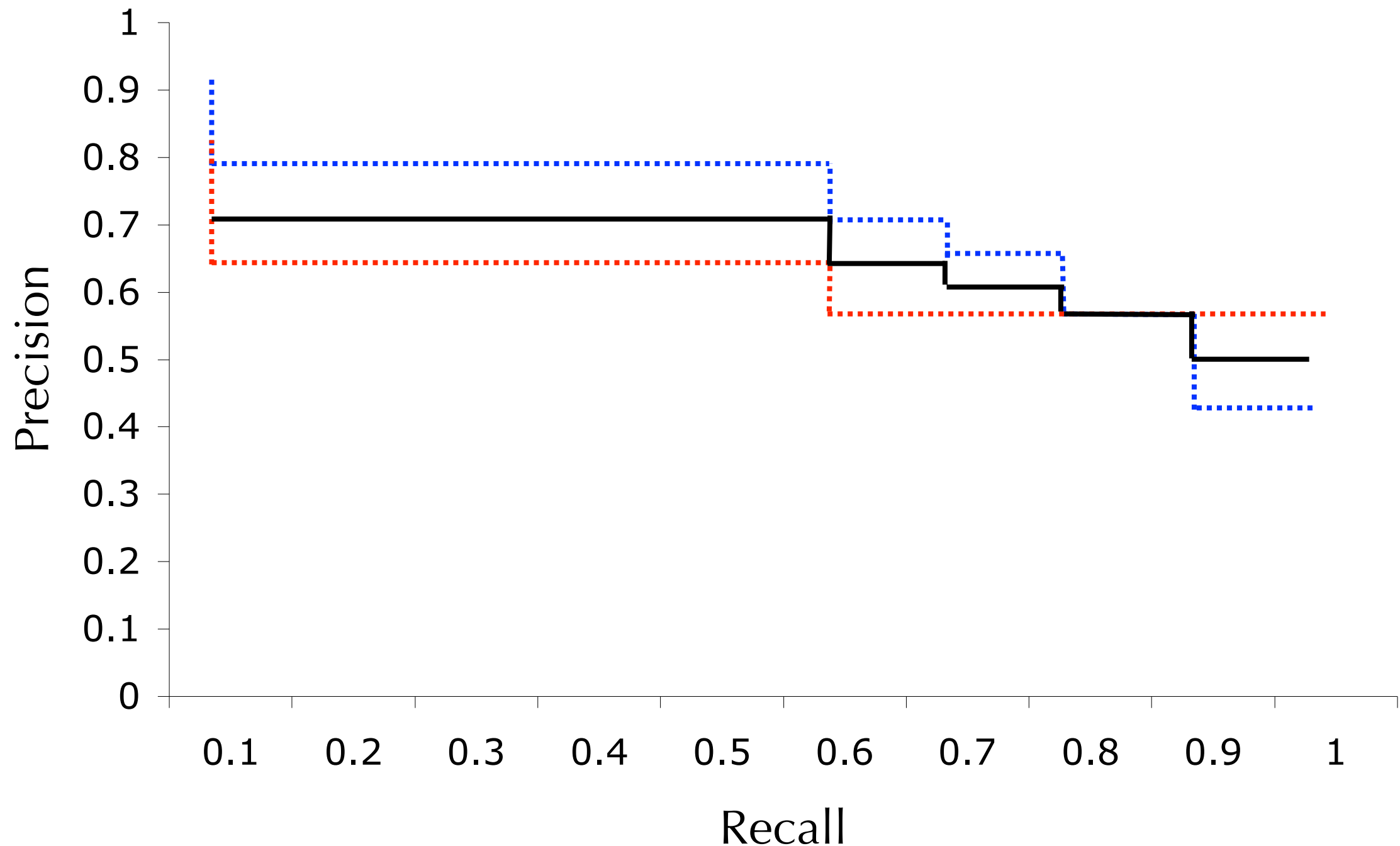
precision-recall curves

- For a single query, a PR curve looks like a step-function
- For multiple queries, we can average these curves
 - ▶ Average the precision values for different values of recall (e.g., from 0.01 to 1.0 in increments of 0.01)
- This forms a smoother function

Ranked Retrieval

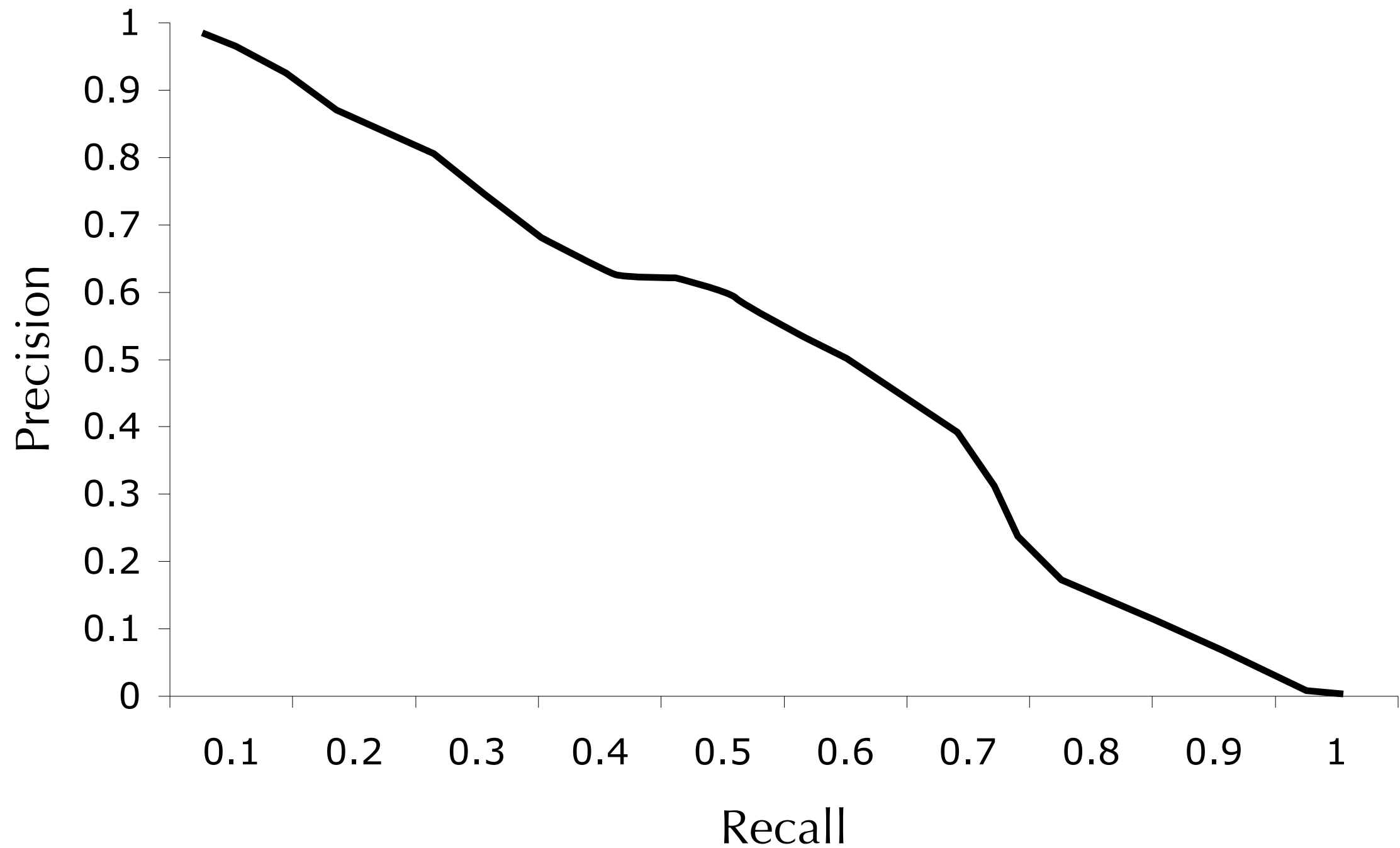
precision-recall curves

- PR curves can be averaged across multiple queries



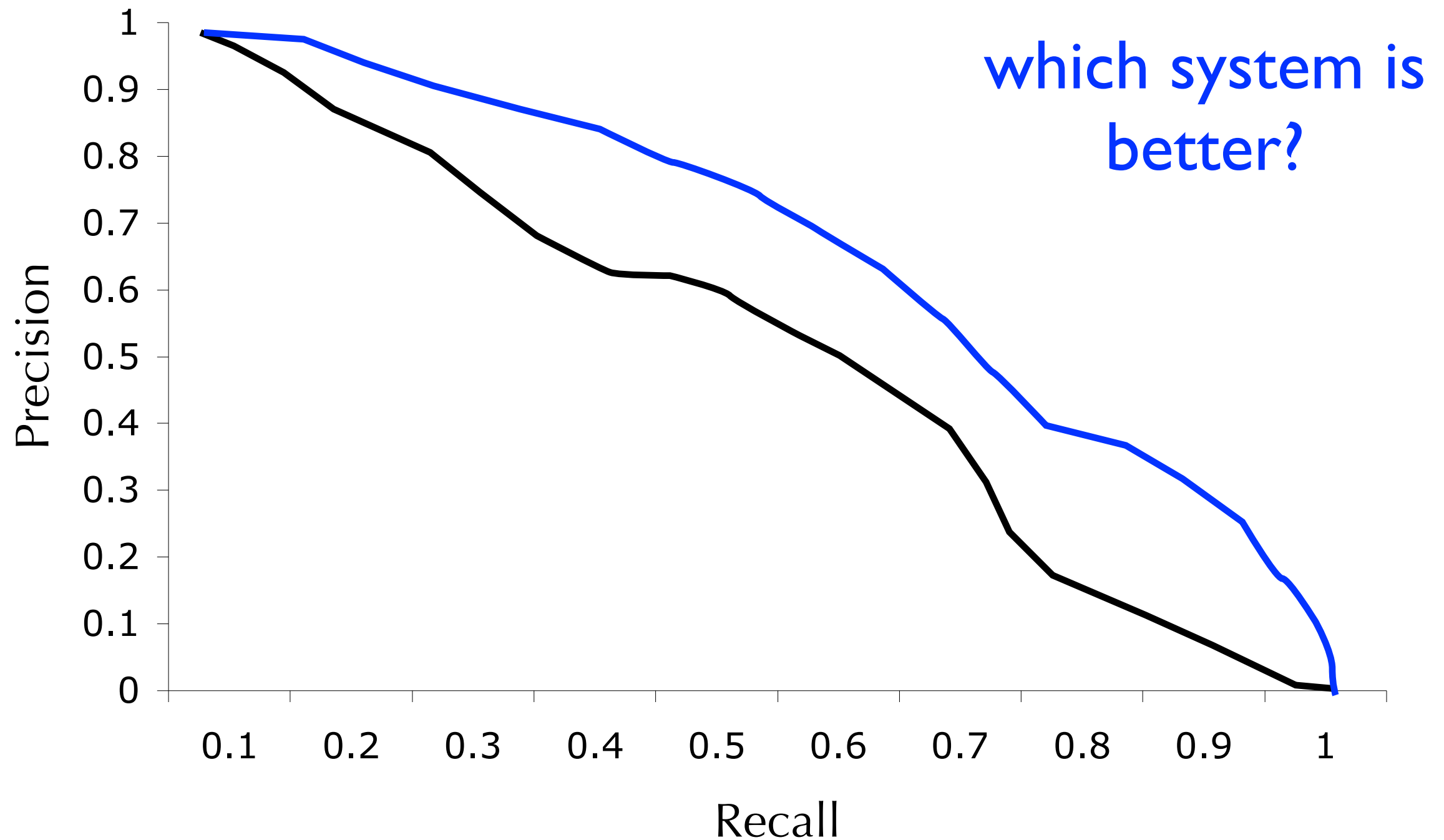
Ranked Retrieval

precision-recall curves



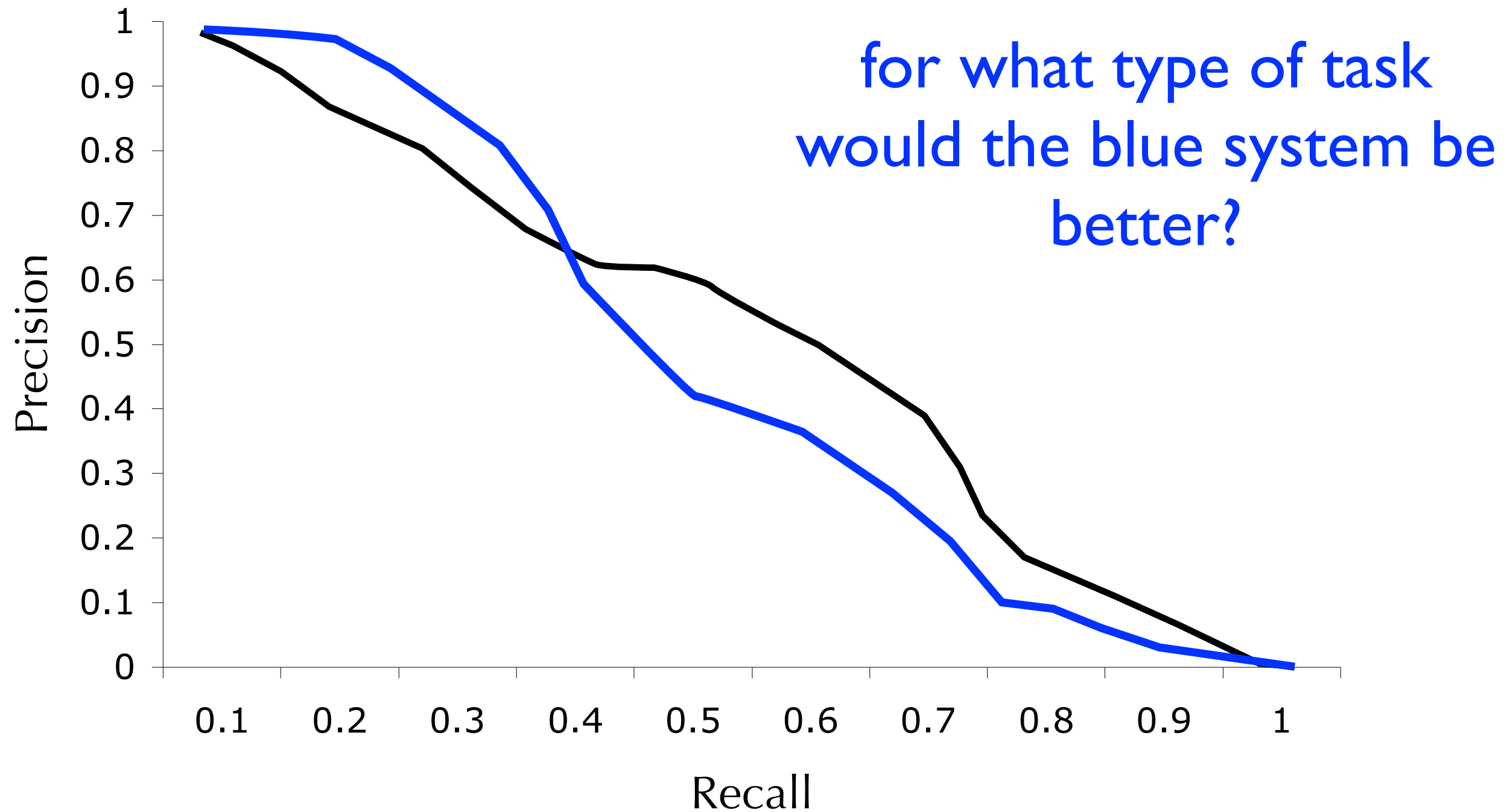
Ranked Retrieval

precision-recall curves



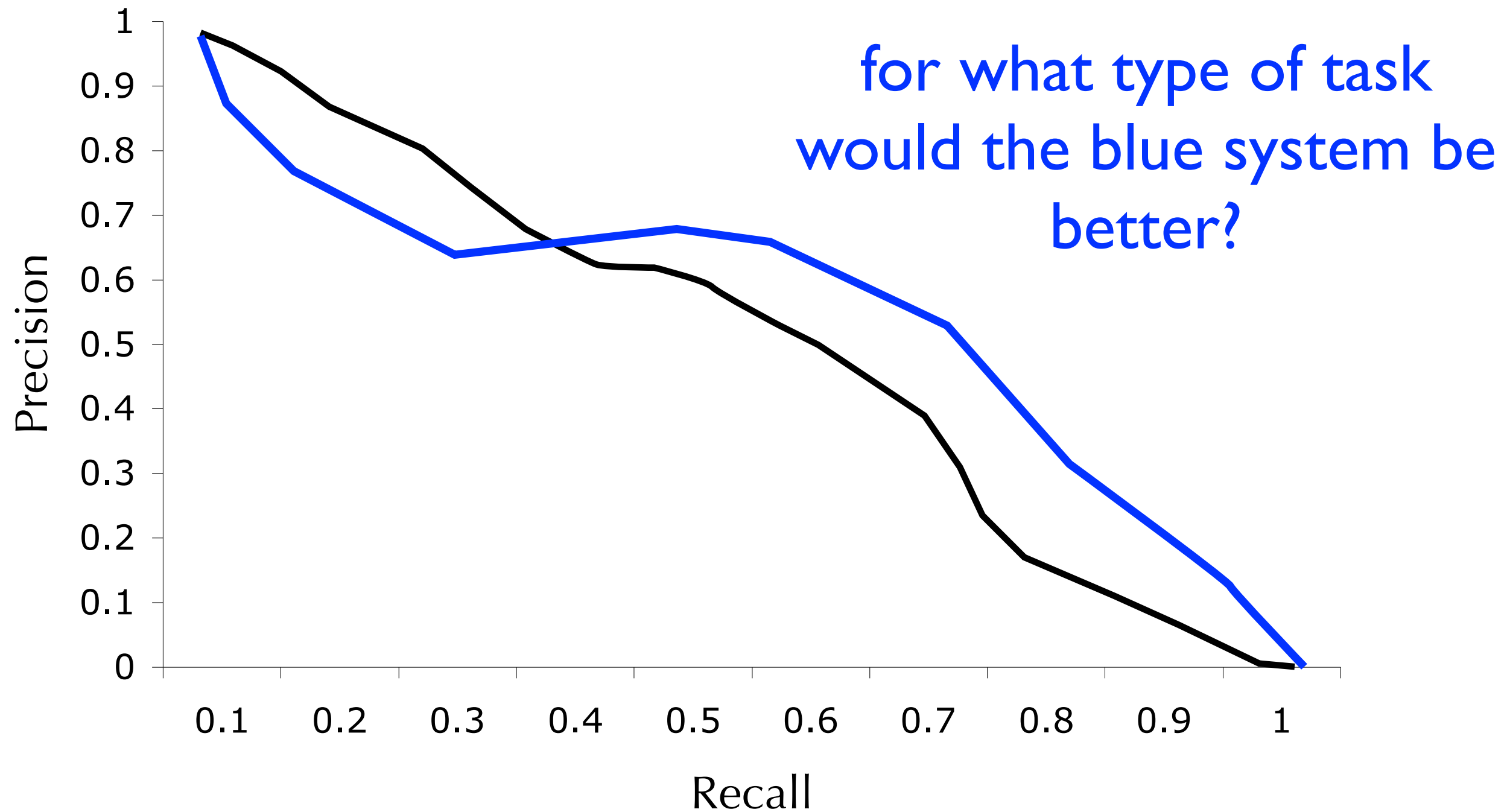
Ranked Retrieval

precision-recall curves



Ranked Retrieval

precision-recall curves



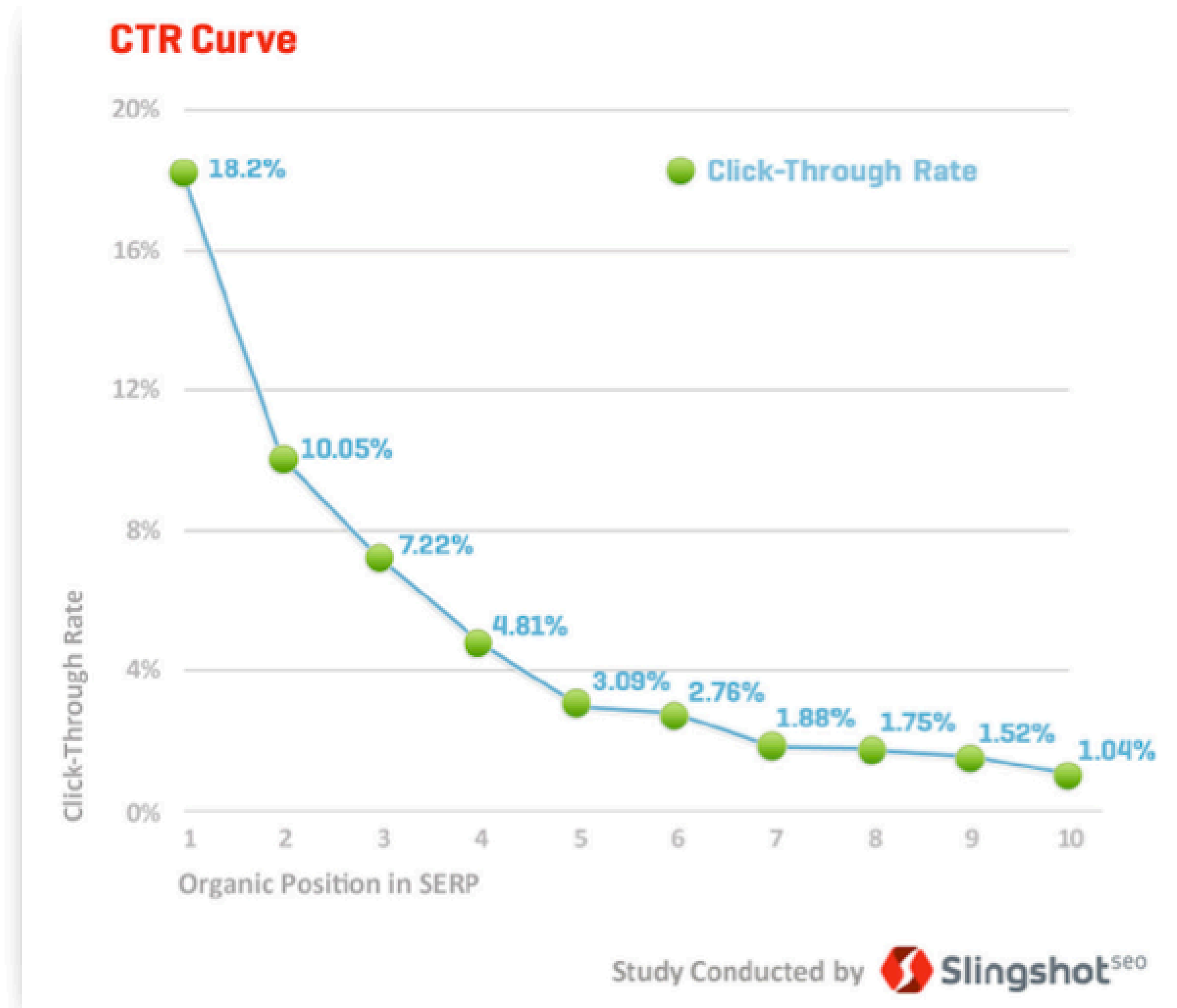
Ranked Retrieval

discounted-cumulative gain

- In some retrieval tasks, we really want to focus on precision at the top of the ranking
- A classic example is web-search!
 - ▶ users rarely care about recall
 - ▶ users rarely navigate beyond the first page of results
 - ▶ users may not even look at results below the “fold”
- Are any of the metrics we’ve seen so far appropriate for web-search?

Ranked Retrieval

discounted-cumulative gain



Ranked Retrieval

discounted-cumulative gain

- We could potentially evaluate using $P@K$ with several small values of K
- But, this has some limitations
- What are they?

Ranked Retrieval

discounted-cumulative gain

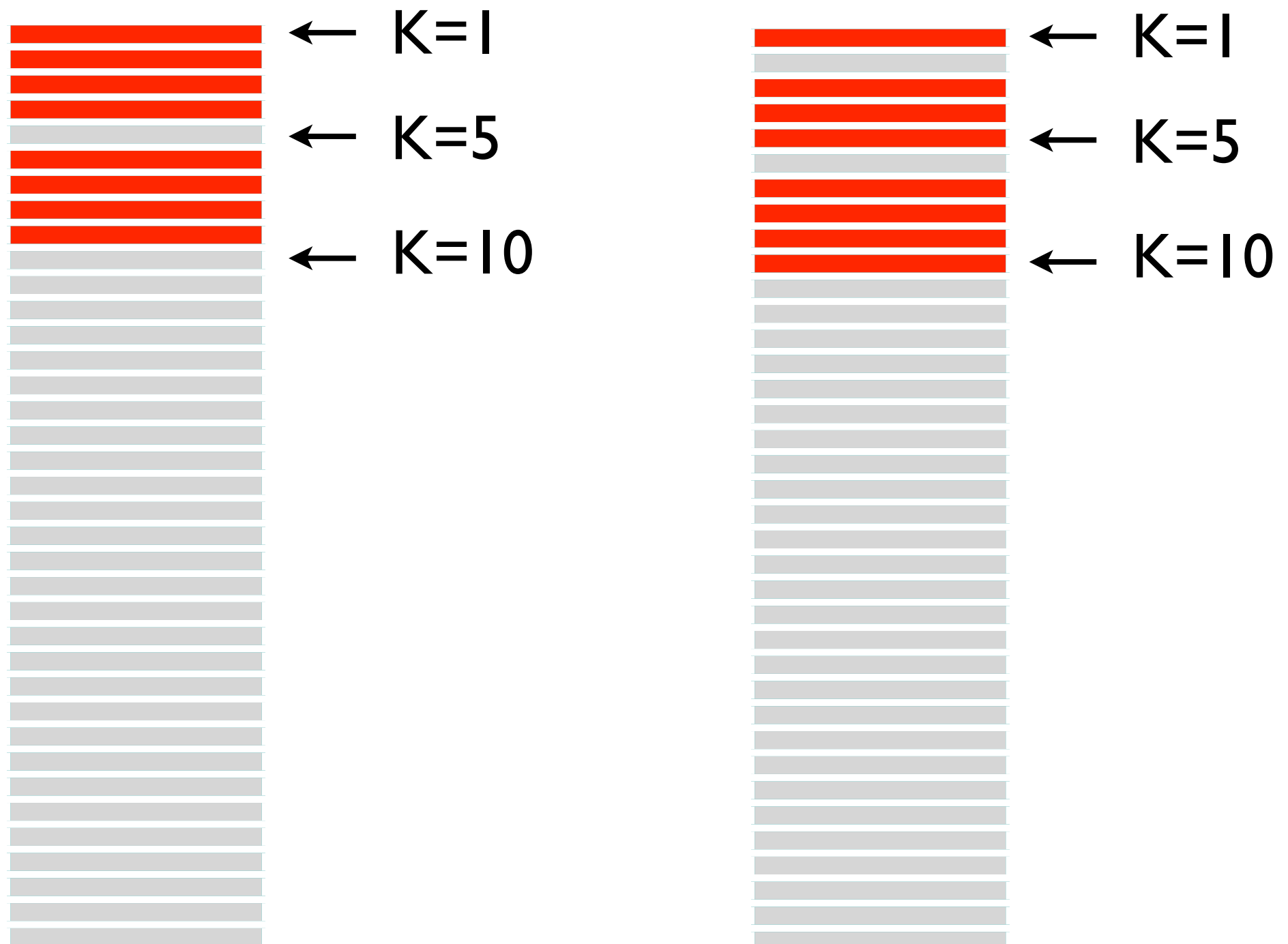
- Which retrieval is better?



Ranked Retrieval

discounted-cumulative gain

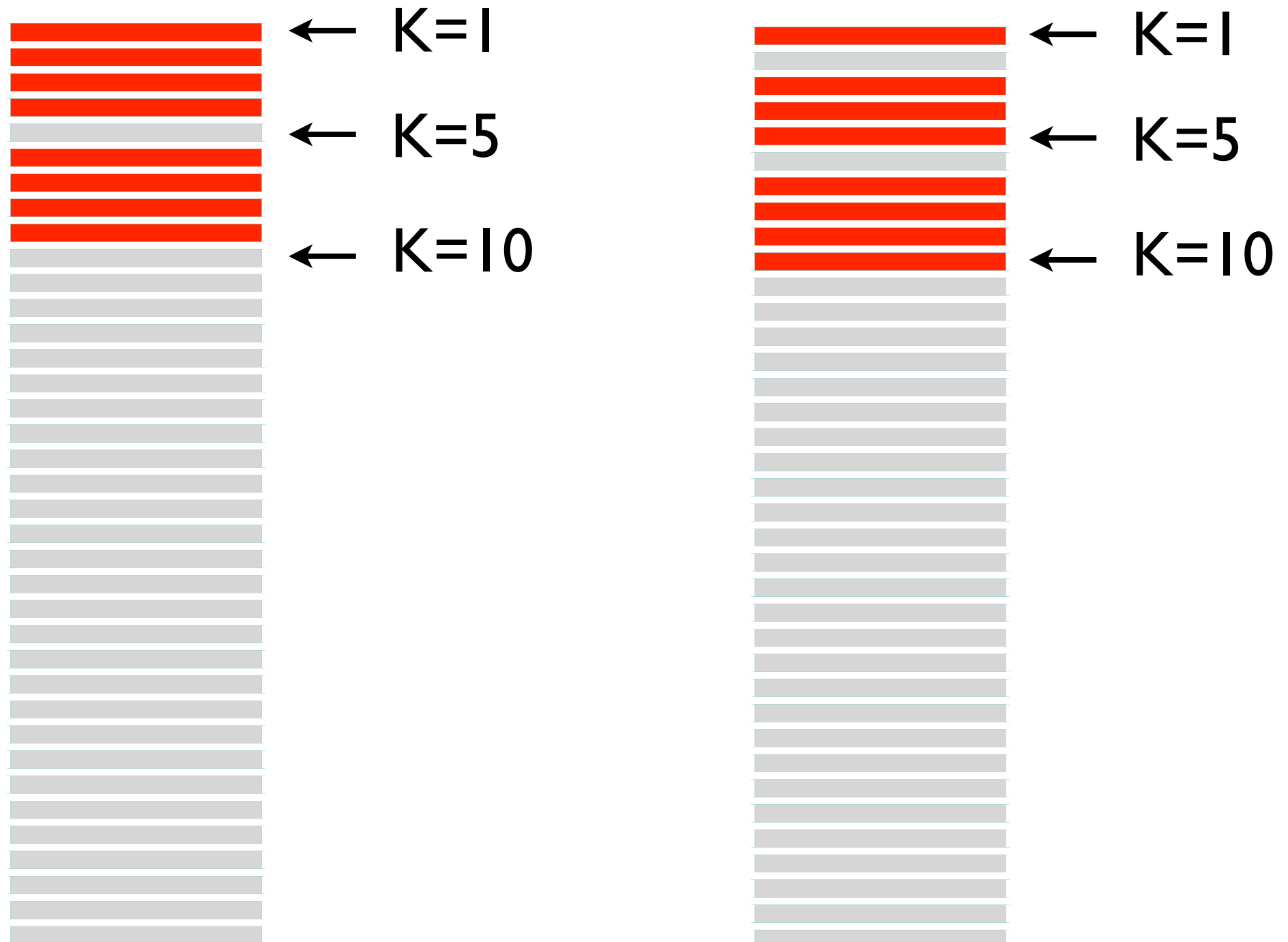
- Evaluation based on $P@K$ can be too coarse



Ranked Retrieval

discounted-cumulative gain

- $P@K$ (and all the metrics we've seen so far) assume binary relevance



Ranked Retrieval

discounted-cumulative gain

- DCG: discounted cumulative gain
- Assumptions:
 - ▶ There are more than two levels of relevance (e.g., perfect, excellent, good, fair, bad)
 - ▶ A relevant document's usefulness to a user decreases rapidly with rank (more rapidly than linearly)

Ranked Retrieval

discounted-cumulative gain

- Let REL_i be the relevance associated with the document at rank i
 - ▶ perfect $\rightarrow 4$
 - ▶ excellent $\rightarrow 3$
 - ▶ good $\rightarrow 2$
 - ▶ fair $\rightarrow 1$
 - ▶ bad $\rightarrow 0$

Ranked Retrieval

discounted-cumulative gain

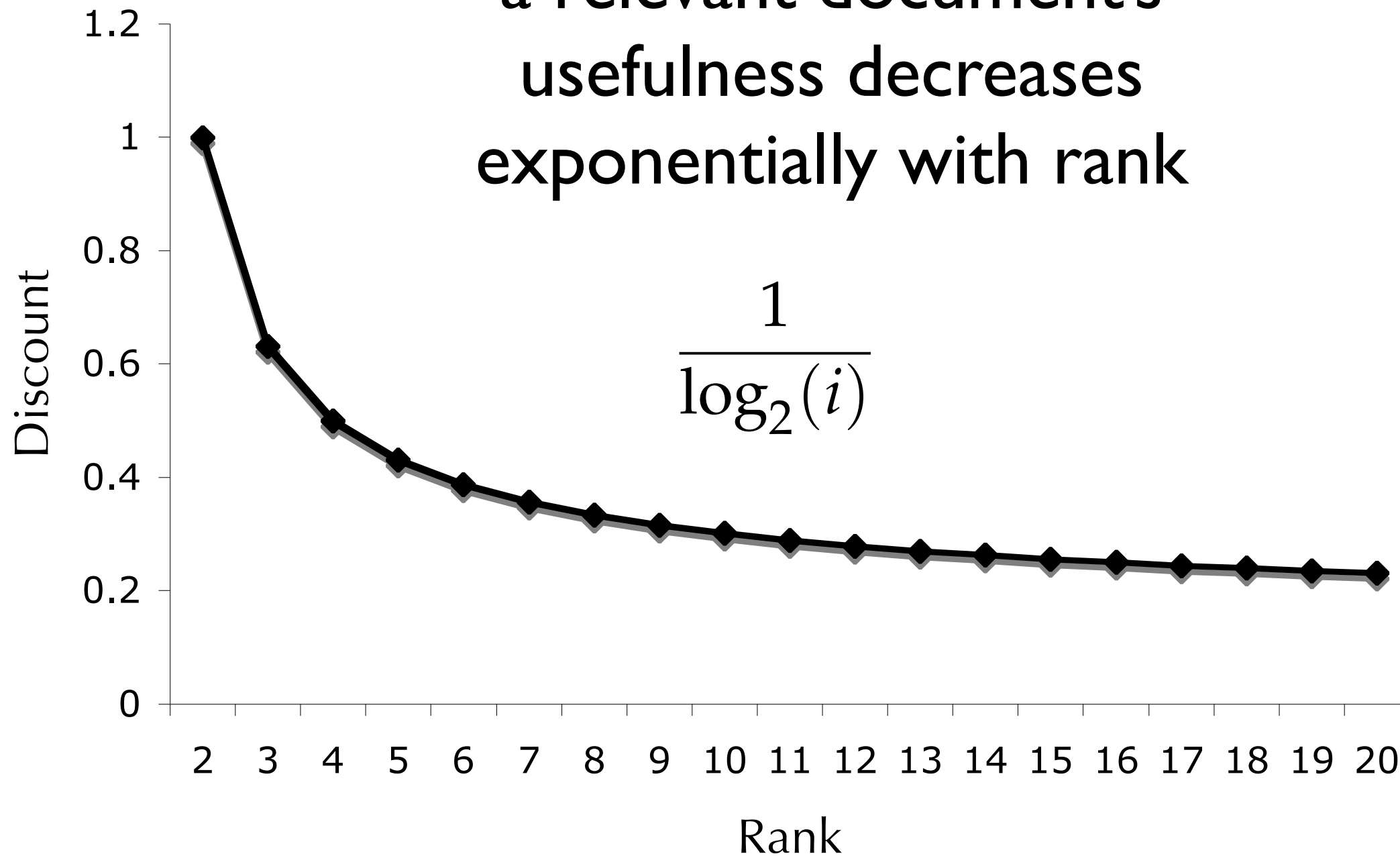
- DCG: discounted cumulative gain

$$DCG@K = \sum_{i=1}^K \frac{REL_i}{\log_2(\max(i, 2))}$$

Ranked Retrieval

discounted-cumulative gain

a relevant document's
usefulness decreases
exponentially with rank



Ranked Retrieval

discounted-cumulative gain

$$DCG@K = \sum_{i=1}^K \frac{REL_i}{\log_2(\max(i, 2))}$$

| rank (i) | REL_i |
|----------|-------|
| 1 | 4 |
| 2 | 3 |
| 3 | 4 |
| 4 | 2 |
| 5 | 0 |
| 6 | 0 |
| 7 | 0 |
| 8 | 1 |
| 9 | 1 |
| 10 | 0 |

This is given!

the result at rank 1 is perfect

the result at rank 2 is excellent

the result at rank 3 is perfect

...

the result at rank 10 is bad

Ranked Retrieval

discounted-cumulative gain

$$DCG@K = \sum_{i=1}^K \frac{REL_i}{\log_2(\max(i, 2))}$$

| rank (i) | REL_i | discount factor |
|----------|-------|-----------------|
| 1 | 4 | 1.00 |
| 2 | 3 | 1.00 |
| 3 | 4 | 0.63 |
| 4 | 2 | 0.50 |
| 5 | 0 | 0.43 |
| 6 | 0 | 0.39 |
| 7 | 0 | 0.36 |
| 8 | 1 | 0.33 |
| 9 | 1 | 0.32 |
| 10 | 0 | 0.30 |

Each rank is associated
with a discount factor

$$\frac{1}{\log_2(\max(i, 2))}$$

rank 1 is a special case!

Ranked Retrieval

discounted-cumulative gain

$$DCG@K = \sum_{i=1}^K \frac{REL_i}{\log_2(\max(i, 2))}$$

| rank (i) | REL_i | discount factor | gain |
|----------|-------|-----------------|------|
| 1 | 4 | 1.00 | 4.00 |
| 2 | 3 | 1.00 | 3.00 |
| 3 | 4 | 0.63 | 2.52 |
| 4 | 2 | 0.50 | 1.00 |
| 5 | 0 | 0.43 | 0.00 |
| 6 | 0 | 0.39 | 0.00 |
| 7 | 0 | 0.36 | 0.00 |
| 8 | 1 | 0.33 | 0.33 |
| 9 | 1 | 0.32 | 0.32 |
| 10 | 0 | 0.30 | 0.00 |

multiply REL_i
by the
discount
factor
associated
with the
rank!

Ranked Retrieval

discounted-cumulative gain

$$DCG@K = \sum_{i=1}^K \frac{REL_i}{\log_2(\max(i, 2))}$$

| rank (i) | REL_i | discount factor | gain | DCG_i |
|----------|-------|-----------------|------|-------|
| 1 | 4 | 1.00 | 4.00 | 4.00 |
| 2 | 3 | 1.00 | 3.00 | 7.00 |
| 3 | 4 | 0.63 | 2.52 | 9.52 |
| 4 | 2 | 0.50 | 1.00 | 10.52 |
| 5 | 0 | 0.43 | 0.00 | 10.52 |
| 6 | 0 | 0.39 | 0.00 | 10.52 |
| 7 | 0 | 0.36 | 0.00 | 10.52 |
| 8 | 1 | 0.33 | 0.33 | 10.86 |
| 9 | 1 | 0.32 | 0.32 | 11.17 |
| 10 | 0 | 0.30 | 0.00 | 11.17 |

Ranked Retrieval

discounted-cumulative gain

$$DCG_{10} = 11.17$$

| rank (i) | REL_i | discount factor | gain | DCG_i |
|----------|-------|-----------------|------|-------|
| 1 | 4 | 1.00 | 4.00 | 4.00 |
| 2 | 3 | 1.00 | 3.00 | 7.00 |
| 3 | 4 | 0.63 | 2.52 | 9.52 |
| 4 | 2 | 0.50 | 1.00 | 10.52 |
| 5 | 0 | 0.43 | 0.00 | 10.52 |
| 6 | 0 | 0.39 | 0.00 | 10.52 |
| 7 | 0 | 0.36 | 0.00 | 10.52 |
| 8 | 1 | 0.33 | 0.33 | 10.86 |
| 9 | 1 | 0.32 | 0.32 | 11.17 |
| 10 | 0 | 0.30 | 0.00 | 11.17 |

Ranked Retrieval

discounted-cumulative gain

$$DCG_{10} = 10.17$$

| rank (i) | REL_i | discount factor | gain | DCG_i |
|----------|-------|-----------------|------|-------|
| 1 | 3 | 1.00 | 3.00 | 3.00 |
| 2 | 3 | 1.00 | 3.00 | 6.00 |
| 3 | 4 | 0.63 | 2.52 | 8.52 |
| 4 | 2 | 0.50 | 1.00 | 9.52 |
| 5 | 0 | 0.43 | 0.00 | 9.52 |
| 6 | 0 | 0.39 | 0.00 | 9.52 |
| 7 | 0 | 0.36 | 0.00 | 9.52 |
| 8 | 1 | 0.33 | 0.33 | 9.86 |
| 9 | 1 | 0.32 | 0.32 | 10.17 |
| 10 | 0 | 0.30 | 0.00 | 10.17 |

changed top result from **perfect** instead of **excellent**

Ranked Retrieval

discounted-cumulative gain

$$DCG_{10} = 11.17$$

| rank (i) | REL_i | discount factor | gain | DCG_i |
|----------|-------|-----------------|------|-------|
| 1 | 4 | 1.00 | 4.00 | 4.00 |
| 2 | 3 | 1.00 | 3.00 | 7.00 |
| 3 | 4 | 0.63 | 2.52 | 9.52 |
| 4 | 2 | 0.50 | 1.00 | 10.52 |
| 5 | 0 | 0.43 | 0.00 | 10.52 |
| 6 | 0 | 0.39 | 0.00 | 10.52 |
| 7 | 0 | 0.36 | 0.00 | 10.52 |
| 8 | 1 | 0.33 | 0.33 | 10.86 |
| 9 | 1 | 0.32 | 0.32 | 11.17 |
| 10 | 0 | 0.30 | 0.00 | 11.17 |

Ranked Retrieval

discounted-cumulative gain

$$DCG_{10} = 12.17$$

| rank (i) | REL_i | discount factor | gain | DCG_i |
|----------|-------|-----------------|------|-------|
| 1 | 4 | 1.00 | 4.00 | 4.00 |
| 2 | 3 | 1.00 | 3.00 | 7.00 |
| 3 | 4 | 0.63 | 2.52 | 9.52 |
| 4 | 2 | 0.50 | 1.00 | 10.52 |
| 5 | 0 | 0.43 | 0.00 | 10.52 |
| 6 | 0 | 0.39 | 0.00 | 10.52 |
| 7 | 0 | 0.36 | 0.00 | 10.52 |
| 8 | 1 | 0.33 | 0.33 | 10.86 |
| 9 | 1 | 0.32 | 0.32 | 11.17 |
| 10 | 3 | 0.30 | 0.90 | 12.08 |

changed 10th result from **bad** to **excellent**

Ranked Retrieval

normalized discounted-cumulative gain

- DCG is not 'bounded'
- In other words, it ranges from zero to
- Makes it problematic to average across queries
- NDCG: normalized discounted-cumulative gain
- "Normalized" is a fancy way of saying, we change it so that it ranges from 0 to 1

Ranked Retrieval

normalized discounted-cumulative gain

- $NDCG_i$: normalized discounted-cumulative gain
- For a given query, measure DCG_i
- Then, divide this DCG_i value by the best possible DCG_i for that query
- Measure DCG_i for the best possible ranking for a given value i

Ranked Retrieval

normalized discounted-cumulative gain

- **Given:** a query has two 4's, one 3, and the rest are 0's
- **Question:** What is the best possible ranking for $i = 1$
- All these are equally good:
 - ▶ 4, 4, 3,
 - ▶ 4, 3, 4,
 - ▶ 4, 0, 0,
 - ▶ ... anything with a 4 as the top-ranked result

Ranked Retrieval

normalized discounted-cumulative gain

- **Given:** the query has two 4's, one 3, and the rest are 0's
- **Question:** What is the best possible ranking for $i = 2$
- All these are equally good:
 - ▶ 4, 4, 3,
 - ▶ 4, 4, 0,

Ranked Retrieval

normalized discounted-cumulative gain

- **Given:** the query has two 4's, one 3, and the rest are 0's
- **Question:** What is the best possible ranking for $i = 3$
- All these are equally good:
 - ▶ 4, 4, 3,

Ranked Retrieval

normalized discounted-cumulative gain

- $NDCG_i$: normalized discounted-cumulative gain
- For a given query, measure DCG_i
- Then, divide this DCG_i value by the best possible DCG_i for that query
- Measure DCG_i for the best possible ranking for a given value i

Metric Review

- **set-retrieval evaluation:** we want to evaluate the set of documents retrieved by the system, without considering the ranking
- **ranked-retrieval evaluation:** we want to evaluate the ranking of documents returned by the system

Metric Review

set-retrieval evaluation

- **precision:** the proportion of retrieved documents that are relevant
- **recall:** the proportion of relevant documents that are retrieved
- **f-measure:** harmonic-mean of precision and recall
 - ▶ a difficult metric to “cheat” by getting very high precision and abysmal recall (and vice-versa)

Metric Review

ranked-retrieval evaluation

- **P@K**: precision under the assumption that the top-K results is the 'set' retrieved
- **R@K**: recall under the assumption that the top-K results is the 'set' retrieved
- **average-precision**: considers precision and recall and focuses mostly on the top results
- **DCG**: ignores recall, considers multiple levels of relevance, and focuses very much on the top ranks
- **NDCG**: trick to make DCG range between 0 and 1

Which Metric Would You Use?



bing



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