CS347

Lecture 7

April 30, 2001

©Prabhakar Raghavan

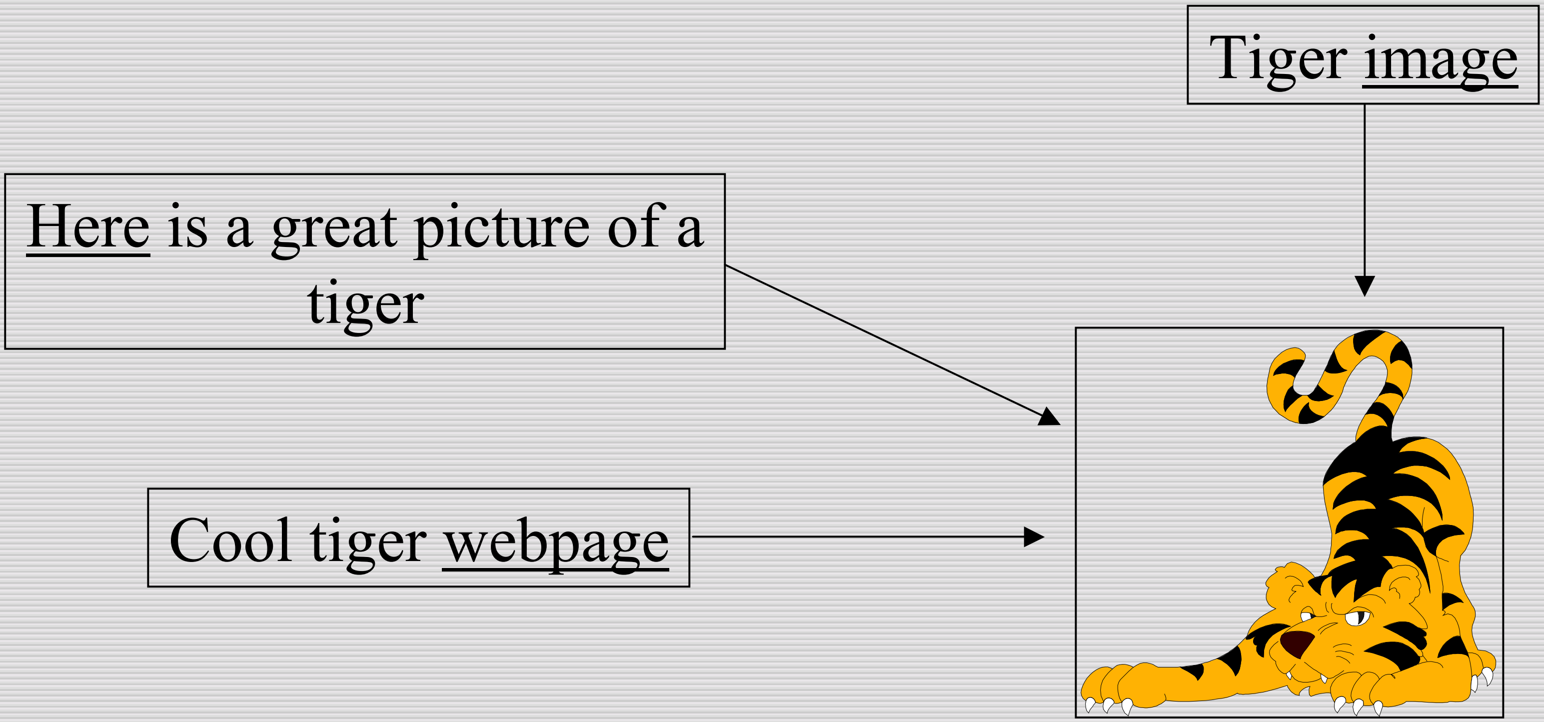
Topics du jour

- Finish up web ranking
- Peer-to-peer search
- Search deployment models
  - Service vs. software
  - External vs. internal-facing search software
- Review of search topics

Tag/position heuristics

- Increase weights of terms in titles
- Increase weights of terms in <h > tags
- Increase weights of terms near the beginning of the doc, its chapters and sections - key phrases

Anchor text



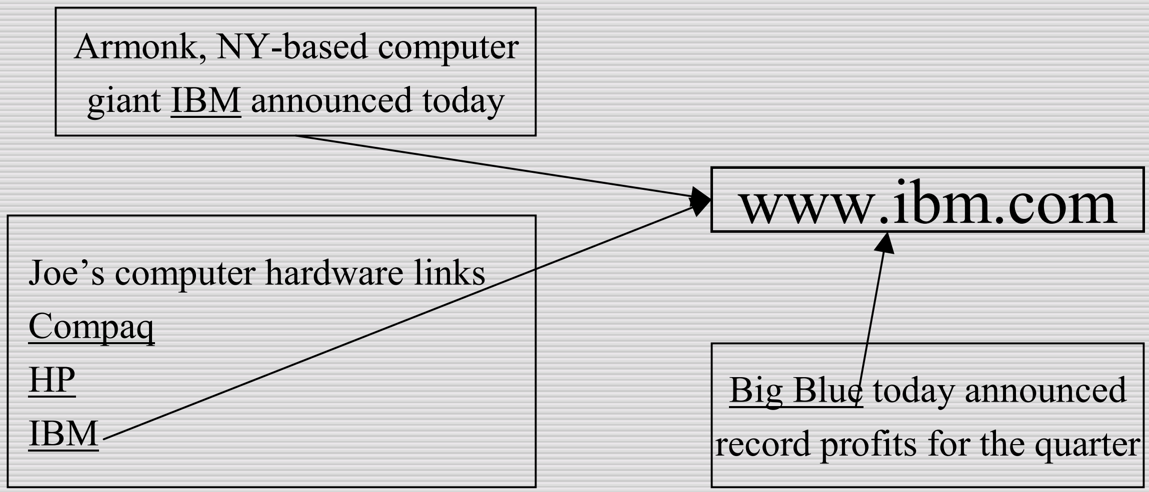
The text in the vicinity of a hyperlink is descriptive of the page it points to.

Two uses of anchor text

- When indexing a page, also index the anchor text of links pointing to it.
- To weight links in the hubs/authorities algorithm from the last lecture.
- Anchor text usually taken to be a window of 6-8 words around a link anchor.

Indexing anchor text

- When indexing a document *D*, include anchor text from links pointing to *D*.



Indexing anchor text

- Can sometimes have unexpected side effects - *e.g.*, ***evil empire***.
- Can index anchor text with less weight.

Weighting links

- In hub/authority link analysis, can match anchor text to query, then weight link.

$$h(x) \leftarrow \sum_{x \quad y} a(y)$$

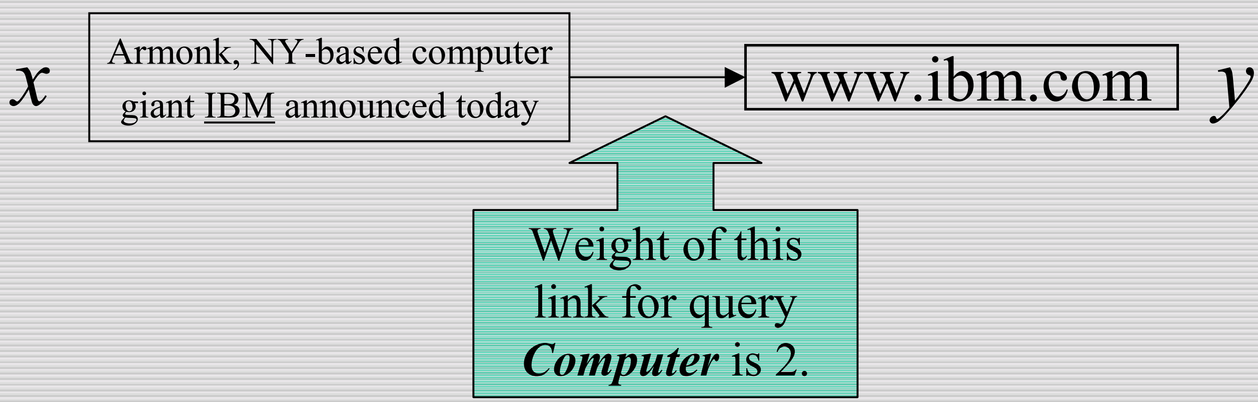
$$a(x) \leftarrow \sum_{y \quad x} h(y)$$

$$h(x) = \sum_{x \quad y} w(x,y) \cdot a(y)$$

$$a(x) = \sum_{y \quad x} w(x,y) \cdot h(y)$$

Weighting links

- What is *w(x,y)*?
- Should increase with the number of query terms in anchor text.
  - Say 1+ number of query terms.



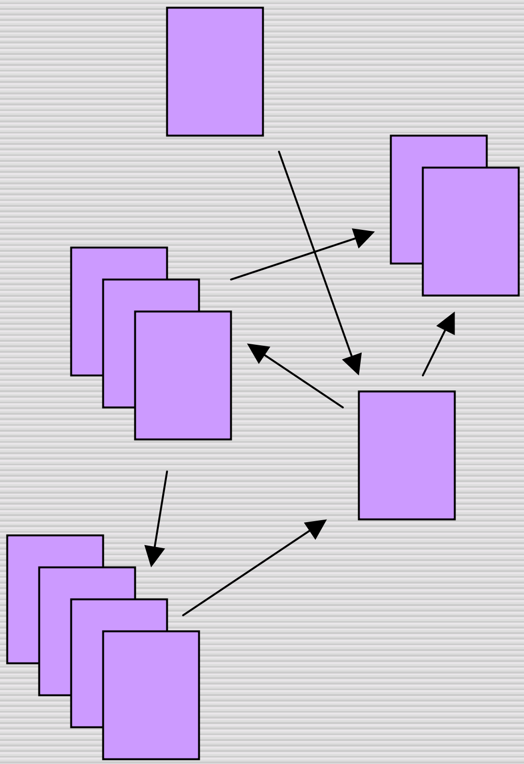
Weighted hub/authority computation

- Recall basic algorithm:
  - Iteratively update all *h(x), a(x)*;
  - After iteration, output pages with highest *h()* scores as top hubs; highest *a()* scores as top authorities.
- Now use weights in iteration.
- Raises scores of pages with "heavy" links.

Do we still have convergence of scores? To what?

Web sites, not pages

- Lots of pages in a site give varying aspects of information on the same topic.



Treat portions of web-sites as a single entity for score computations.

Link neighborhoods

- Links on a page tend to point to the same topics as neighboring links.
  - Break pages down into *pagelets* (say separate by tags) and compute a hub/authority score for each pagelet.

Link neighborhoods

Ron Fagin's links

- Logic links
    - Moshe Vardi's logic page
    - International logic symposium
    - Paper on modal logic
- ….
- My favorite football team
    - The 49ers
    - Why the Raiders suck
    - Steve's homepage
    - The NFL homepage

Web vs. hypertext search

- The WWW is full of free-spirited opinion, annotation, authority conferral
- Most other forms of hypertext are far more structured
  - enterprise intranets are regimented and templated
  - very little free-form community formation
  - web-derived link ranking doesn’t quite work

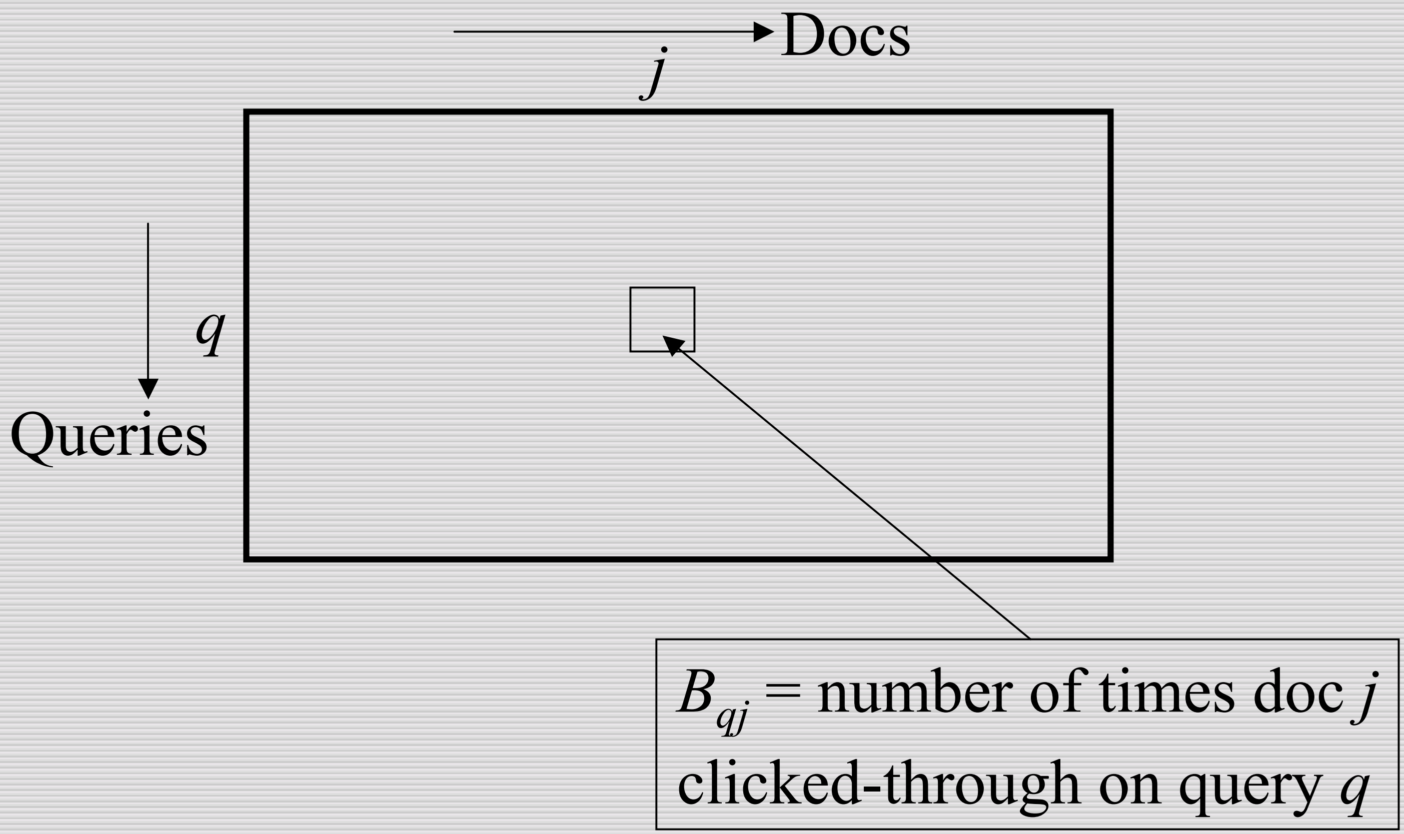
Link analysis/search - summary

- Powerful new ideas
  - derived from sociology of web content creation
- Supplemented by other heuristics
- Less useful in intranets
- Challenges from dynamic html
- Application servers and web content management systems

Behavior-based ranking

- For each query *Q*, keep track of which docs in the results are clicked on
- On subsequent requests for *Q*, re-order docs in results based on click-throughs
- First due to DirectHit $\rightarrow$AskJeeves

Query-doc popularity matrix **B**



When query q issued again, order docs by B_{qj} values.

Issues to consider

- Weighing/combining text- and click-based scores.
- What identifies a query?
  - Ferrari Mondial
  - Ferrari   Mondial
  - Ferrari mondial
  - ferrari mondial
  - "Ferrari Mondial"
- Can use heuristics, but search parsing slowed

Vector space implementation

- Maintain a term-doc popularity matrix **C**
  - as opposed to query-doc popularity
  - initialized to all zeros
- Each column represents a doc *j*
  - If doc *j* clicked on query **q**, update $C_j \leftarrow C_j + \varepsilon \mathbf{q}$ (here **q** is viewed as a vector).
- On a query **q'**, compute its cosine proximity to C_j for all *j*.
- Combine this with the regular text score.

Issues

- Normalization of C_j after updating.
- Boolean operators
- Why did the user click on the doc?
- Updating - live or batch?
- All votes count the same.
  - More on this in recommendation systems.

Variants

- Time spent viewing page
  - Difficult session management
  - Inconclusive modeling so far.
- Does user back out of page?
- Does user stop searching?
- Does user transact?

Peer-to-peer (P2P) search

- No central index
- Each node in a network builds and maintains own index
- Each node has "servent" software
  - On booting, servent pings ~4 other hosts
  - Connects to those that respond
  - Initiates, propagates and serves requests

Which hosts to connect to?

- The ones you connected to last time
- Random hosts you know of
- Request suggestions from central (or hierarchical) nameservers

- All govern system's shape and efficiency

Serving P2P search requests

- Send your request to your neighbors
- They send it to their neighbors
  - decrement "time to live" for query
  - query dies when ttl = 0
- Send search matches back along requesting path

The promise of P2P

- Fresh content
  - no waiting for the next weekly indexing
- Dynamic content
  - results could be assembled from a database or other repository
  - live pricing/inventory information

P2P search issues

- Internet:
  - Query interpretation up to servent
    - spamming potential
  - No co-ordination in network
    - fragmentation
- Enterprises:
  - security and access control
  - administration
  - distributed replication and caching

Search deployment

Intranet vs. extranet

Search deployment models

- As a service
  - public, e.g., web search
  - access-protected, e.g., proprietary newsfeeds and content
- As software
  - Outward-facing (Walmart, CDNow …)
  - Inward-facing within an enterprise

Service deployment issues

+ Ease of maintenance
  + software as well as indices
+ Can tune to platform

- To date, not much proprietary content
  – owners of valuable content don't hand over custody

Software deployment

- Inward vs. outward-facing
  - very different characteristics
    - corpus sizes
    - query rates
    - languages and localization
    - security
    - content management

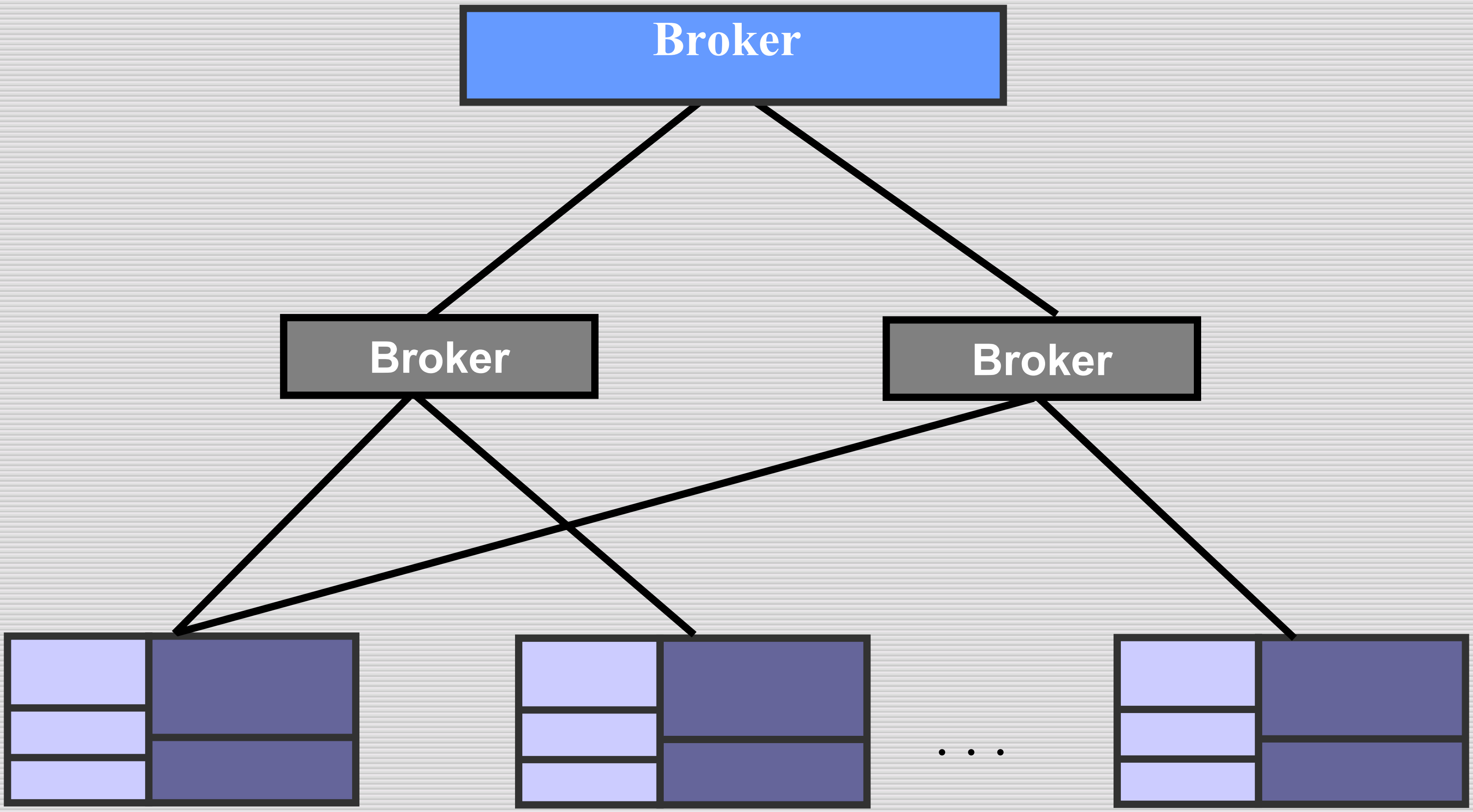
Outward-facing search software

- Relatively small corpora
  - typically under 1GB
- Sporadic query rates, high peak loads
- Fairly dynamic corpus
  - item prices in a catalog

Typical eCommerce search setup

- Product database (RDBMS) w/product info
  - prices, descriptions
- Search engine - spiders DB, indexes structured+unstructured product info.
- Application server - content assembly, personalization + Web server
- Back-end inventory RDBMS
  - to complete the transaction.

Scaling search servers



Search servers

Partitioning the index

- By documents
  - Each server has a subset of the docs
  - Each has its own dictionary
  - Query sent out to “all” servers
- Broker ensures load-balancing, failover

Partitioning the index

- By terms
  - Each server has a subset of the lexicon
  - Query sent to server(s) with the query term(s)
  - Partition alphabetically→easy query dispatch
  - Partition by hashing →uniform spread
- Query optimization is hard
- Works best when query terms are uniformly spread across servers

Inward-facing search software

- Search within an intranet
- Enterprise portals

“Enterprise” doesn’t have to be a (for profit) company - government, academe, … any collaborative group with proprietary information.

Issues in enterprise search

- Scale - lots of docs, geographically distributed over non-uniform WAN
- Multiple languages and character sets
  - Locale modules for stemming, thesauri
- Multiple document repositories
  - Lotus, Exchange, Documentum, Filenet …
  - Materialized views of compound documents
- Multiple formats - pdf, MS office, …
  - multiple MIME-type attachments

Security and results lists

- Each doc has access permissions for groups
- User authenticated for membership in certain groups; can change with time
- Results of a search should only contain docs the user can view
  - Not sufficient to show a doc in results, then deny user attempting to access it
- Compound docs made up of pieces
  - each piece has own ACL's

Bottom line

- Enterprise search - inside and outside - are quite different
- Each different from public web search service
- Inside enterprise search the most fragile
  - tremendous diversity
  - flexible, hard-to-administer software vs. expensive customization

Review of search topics

Inverted index

- Dictionary of terms
- Each term points to a series of *postings* entries
  - Postings for a term point to docs containing that term

Term storage in dictionary

- Store pointers to every *k*th on term string.
- Need to store term lengths (1 extra byte)

….7systile9syzygetic8syzygial6syzygy11szaibelyite8szczecin9szomo….

Freq.	Postings ptr.	Term ptr.
33		
29		
44		
126		
7		

Save 9 bytes on 3 pointers.

Lose 4 bytes on term lengths.

Postings file entry

- Store list of docs containing a term in increasing order of doc id.
  - ***Brutus***: 33,47,154,159,202 …
- Suffices to store gaps.
  - 33,14,107,5,43 …
- Gaps encoded with far fewer than 20 bits, using γ codes.

Total postings size

- Estimate using crude Zipf law analysis
  - Most frequent term occurs in *n* docs
  - Second most frequent term in *n/2* docs
  - *k*th most frequent term in *n/k* docs, etc.
    - *n/k* gaps of *k* each - use ~$2\log_2 k$ bits for each gap using γ codes.

What gets indexed?

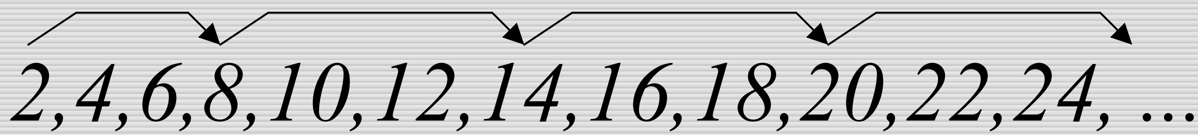
- Stemming - Porter’s.
- Case folding.
- Thesauri and soundex
- Spell correction

Query optimization

- Consider a query that is an *AND* of *t* terms.
- The idea: for each of the *t* terms, get its term-doc incidence from the postings, then *AND* together.
- Process in order of increasing freq:
  - *start with smallest set, then keep cutting further.*

This is why we kept freq in dictionary.

Skip pointers



- At query time:
- As we walk the current candidate list, concurrently walk inverted file entry - can skip ahead
  - (*e.g.*, 8,21).
- Skip size: recommend about $\sqrt{\text{(list length)}}$

Wild-card queries

- ***mon****: find all docs containing any word beginning "mon".
- Solution: index all *k*-grams occurring in any doc (any sequence of *k* chars).
- Query *mon** can now be run as
  - ***$m AND mo AND on***
  - But we'd get a match on *moon*.
- Must post-filter these results against query.

Phrase search

- Search for ***"to be or not to be"***
- No longer suffices to store only <*term*:*docs*> entries.
- Instead store, for each ***term***, entries
  - <number of docs containing ***term***;
  - *doc1*: position1, position2 … ;
  - *doc2*: position1, position2 … ;
  - etc.>

Precision and recall

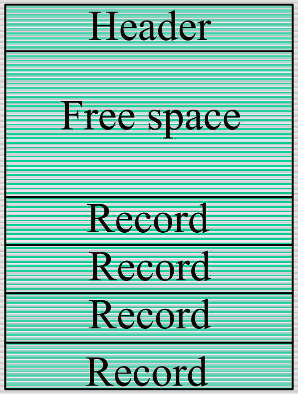
- Precision: fraction of retrieved docs that are relevant
- Recall: fraction of relevant docs that are retrieved
- Both can be measured as functions of the number of docs retrieved

Index construction

- Parse and build postings entries one doc at a time
- To now turn this into a term-wise view, must sort postings entries by term (then by doc within each term)
- Block of postings records; can “easily” fit a couple into memory.
- Sort within blocks first, then merge.

Fully dynamic updates

- Inserting a (variable-length) record
  - a typical postings entry
- Maintain a pool of (say) 64KB *chunks*
- Chunk header maintains metadata on records in chunk, and its free space



Doc as vector

- Each doc *j* can now be viewed as a vector of *tf*×*idf* values, one component for each term.
- So we have a vector space
  - terms are axes
  - docs live in this space
  - even with stemming, may have 10000+ dimensions

tf x idf

$$w_{ij} = tf_{ij} \times \log(n / n_i)$$

tf_{ij} = frequency of term i in document j

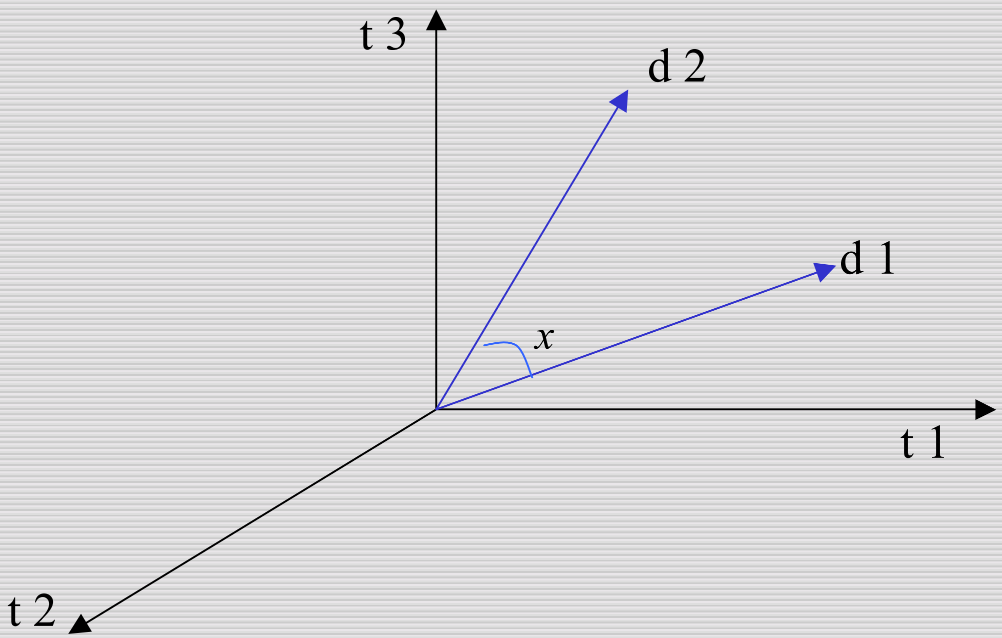
n = total number of documents

n_i = the number of documents that contain term i

$idf_i = \log\left(\frac{n}{n_i}\right)$ = inverse document frequency of term i

Cosine similarity

- Distance between vectors *D1,D2 captured* by the cosine of the angle *x* between them.
- Note - this is similarity, not distance.



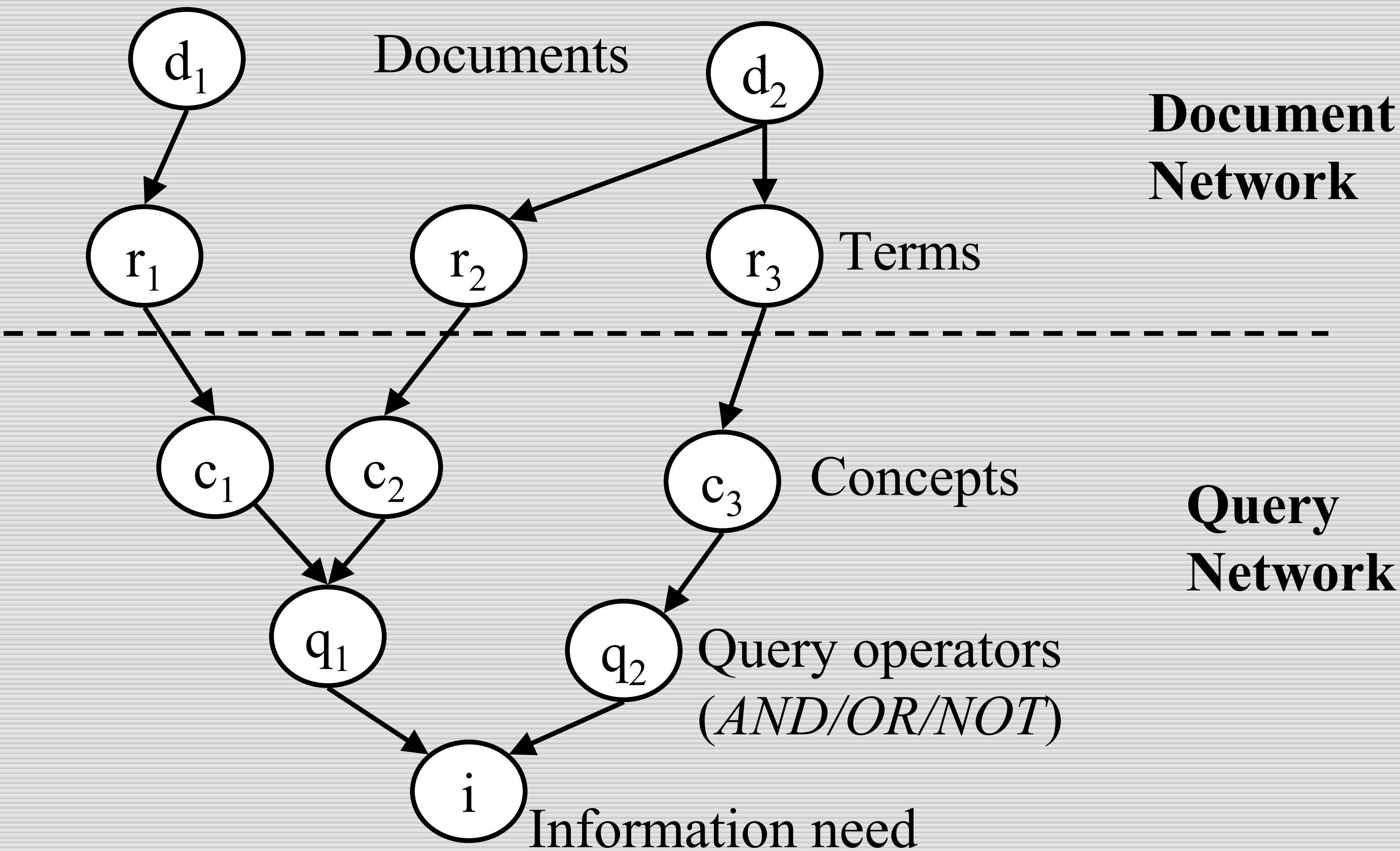
The point of using vector spaces

- **<u>Key</u>**: A user's query can be viewed as a (very) short document.
- Query becomes a vector in the same space as the docs.
- Can measure each doc's proximity to it.
- Natural measure of scores/ranking - no longer Boolean.

Search using vector spaces

- Computing individual cosines
- Speeding up computations
  - Avoiding computing cosines to all docs
  - Dimensionality reduction
    - Random projection
    - LSI

Bayesian nets for text retrieval



Semi-structured search

- Structured search - search by restricting on attribute values, as in databases.
- Unstructured search - search in unstructured files, as in text.
- Semi-structured search: combine both.

Link analysis

- Two basic approaches
  - Universal, query-independent ordering on all web pages (based on link analysis)
    - Of two pages meeting a (text) query, one will always win over the other, *regardless* of the query
  - Query-specific ordering on web pages
    - Of two pages meeting a query, the relative ordering may vary from query to query

Ergodic Markov chains

- For any ergodic Markov chain, there is a unique long-term visit rate for each state.
  - *Steady-state distribution*.
- Over a long time-period, we visit each state in proportion to this rate.
- <u>It doesn't matter where we start.</u>

Resources

- MIR 9.