# Searching the Web

Uke 42 – Lecture 9

# Brief (non-technical) history

- Early keyword-based engines
  - Altavista, Excite, Infoseek, Inktomi
- Sponsored search ranking: Goto.com (morphed into Overture.com → Yahoo!)
  - Your search ranking depended on how much you paid
  - Auction for keywords: ***casino*** was expensive!

# Brief (non-technical) history

- 1998+: Link-based ranking pioneered by Google
  - Blew away all early engines save Inktomi
  - Great user experience in search of a business model
  - Meanwhile Goto/Overture's annual revenues were nearing $1 billion
- Result: Google added paid-placement "ads" to the side, independent of search results
  - Yahoo followed suit, acquiring Overture (for paid placement) and Inktomi (for search)

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Google bildeler

Alle | Bilder | Google Maps | Videoer | Shopping | Mer | Innstillinger | Verktøy

Omtrent 3 470 000 resultater (0,48 sekunder)

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# Searching the Web

- Three forms of searching

1. **Specific queries** ⇒ encyclopaedia, libraries
   - Exploit hyperlink structure
2. **Broad queries** ⇒ web directories
   - Web directories: classify web documents by subjects
3. **Vague queries** ⇒ search engines
   - index portions of web

# Problem with the data

- **Distributed** data
- High percentage of **volatile data** – much is generated
- **Large** volume
  - June 2000 Google full-text index of 560 million URLs
- **Unstructured** data
  - gifs, pdf etc
- **Redundant** data
  - – mirrors (30% pages are near duplicates)
- **Quality** of data
  - false, poorly written, invalid, misspelt
- **Heterogeneous** data – media, formats, languages, alphabets

# Search Engines

- Difference between standard IR systems
  - Only indices available, no text
- If insisting on text availability
  - **Keep local copy** of the Web pages
    - Too expensive
  - Access the remote Web pages
    - Too slow
- Architectures
  - **Centralized**
    - More popular
  - **Distributed**



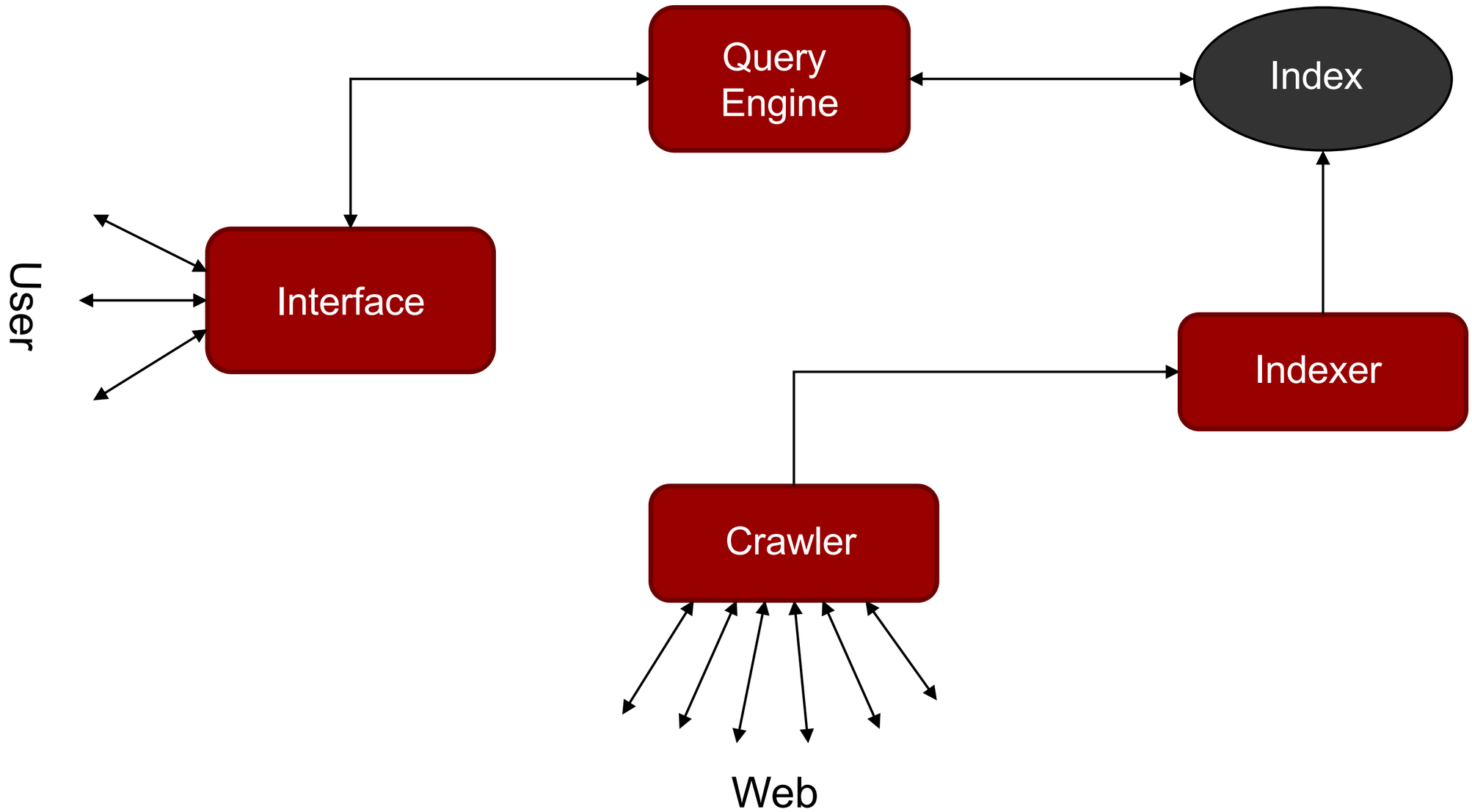




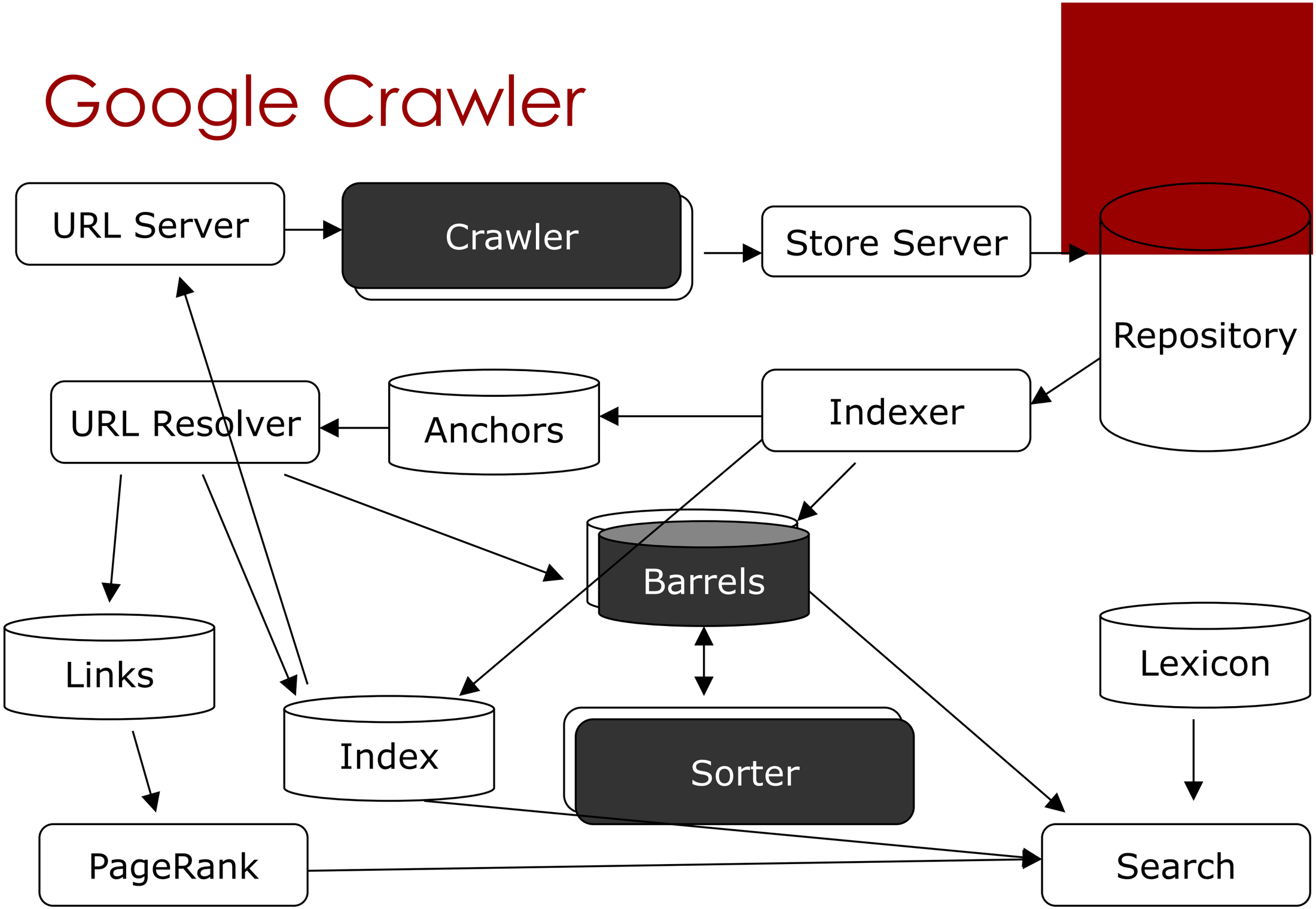
# Centralized Architecture

- Centralized crawler-indexer architecture
- Crawlers
  - Software agents that traverse the Web and send new or updated pages to the server
  - Aka, robots, spiders, wanderers, walkers, knowbots
  - Usually the code does not move to the remote machines
  - Just send the request to the remote machines

# Centralized Architecture (2)



# Google Crawler




Google

# Robots Exclusion Protocol

- http://www.mydomain.com/robots.txt

```
User-agent: *
Disallow: /cgi-bin/
Disallow: /tmp/
Disallow: /~joe/
```

- HTML META Tag

```
<HTML>
<HEAD>
<META NAME="ROBOTS" CONTENT="NOINDEX, NOFOLLOW">
</HEAD>
…
```

# Centralized Architecture (3)

- AltaVista architecture
  - Two parts: one for users, one for the indexing
  - 20 multiprocessor machines, 130 Gb of RAM, 500 Gb of disk
  - The query engine use most of these resources (70%)

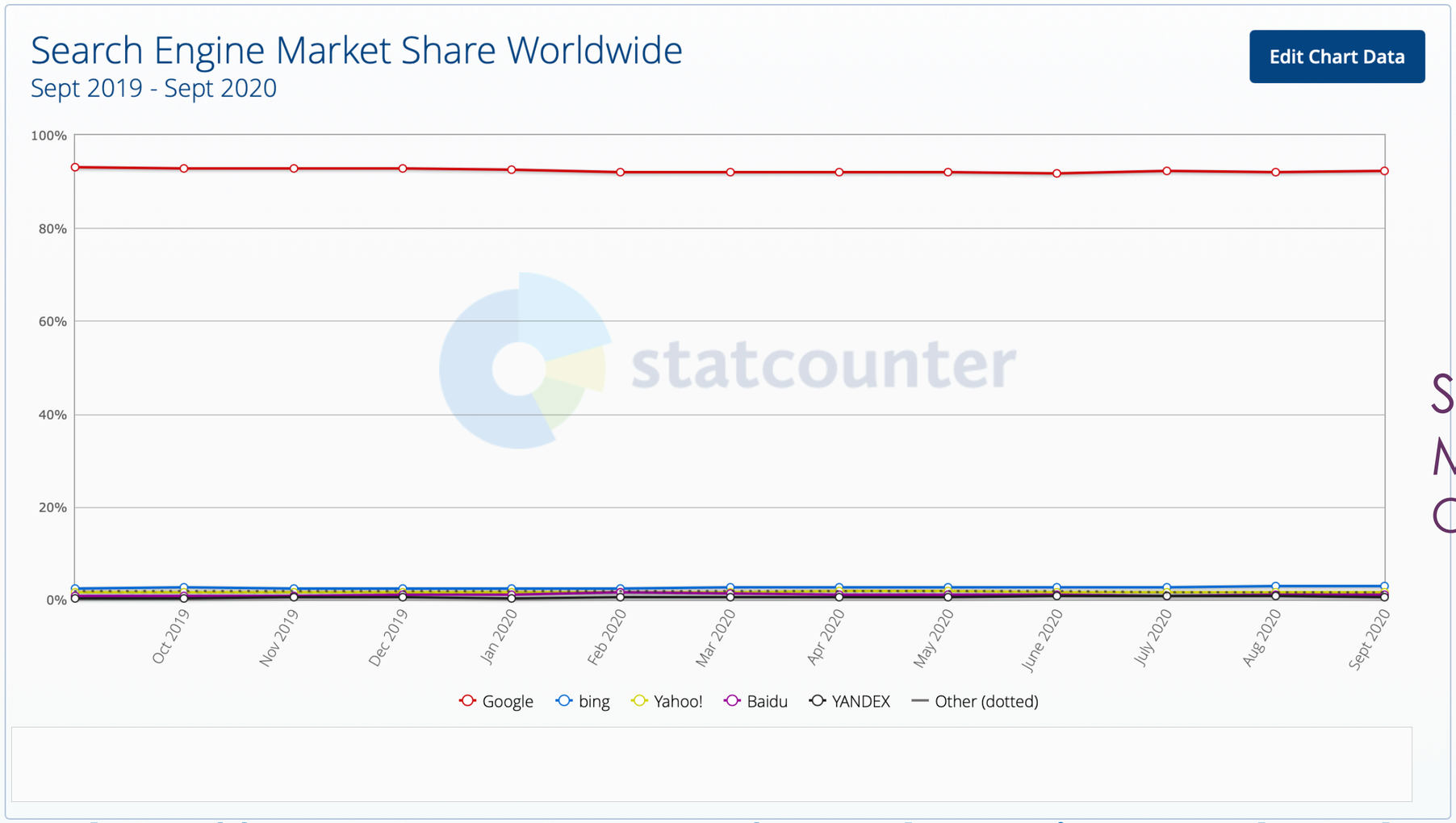
# Centralized Architecture (4)

- Problem of the centralized architecture
  - Gathering of the data
    - Web is dynamic
  - Communication lines
  - High load at Web servers

# Centralized Architecture (5)

- The largest search engines (in 1998!)
  - AltaVista > HotBot > Northern Light > Excite
    - in terms of Web coverage
    - They cover 28-55% (or 14-34%) of all Web pages (300 million) in 1998
  - Some are using the same internal engine
    - HotBot, GoTo, Microsoft by Inktomi
    - Magellan by Excite's
- Largest today: Google

# Global Share: Web Search

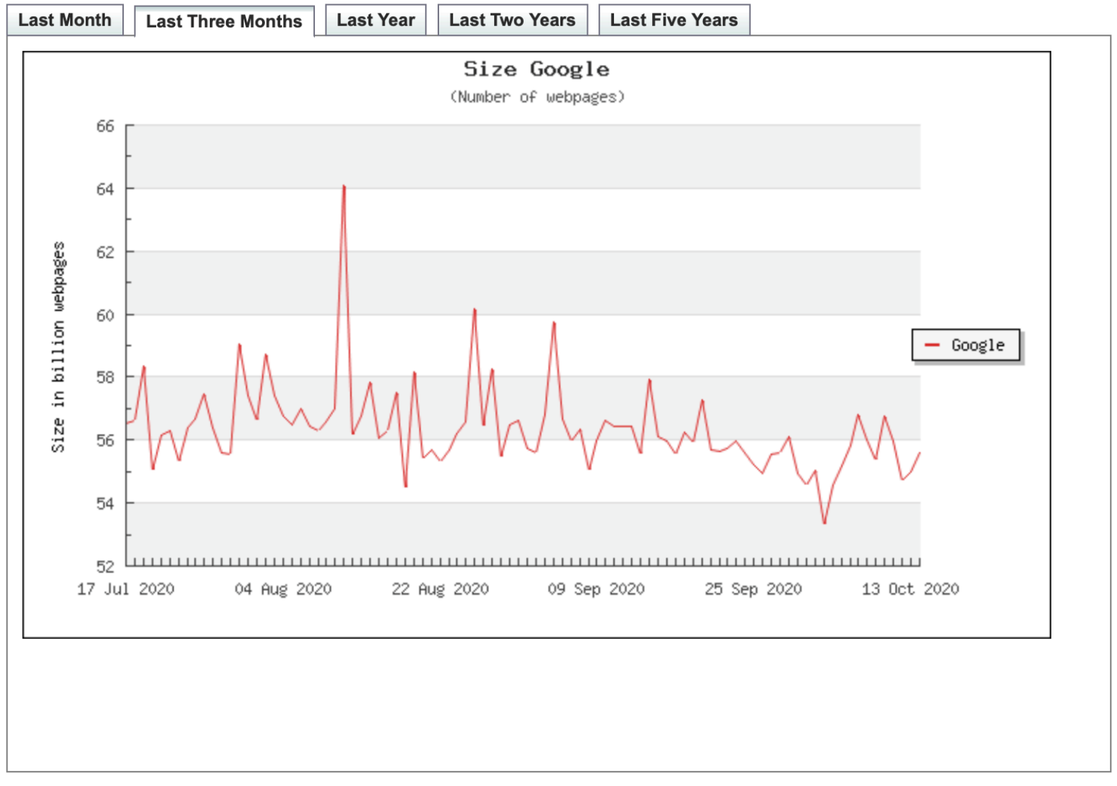




Search Engine Market Share Oct. 2020

http://gs.statcounter.com/search-engine-market-share

- The best web engine:
  - comprehensive and relevant results
- Biggest index
  - > 5.5 billion pages visited and recorded
- Different kinds of index
  - smaller indexes containing a higher amount of the web's most popular pages, as determined by Google's link analysis system.
- Index refresh
  - Updated monthly/weekly
  - Daily for popular pages
- Serves queries from three data centres
  - two on West Coast of the US, one on East Coast.

**The size of the World Wide Web:**
**Estimated size of Google's index**



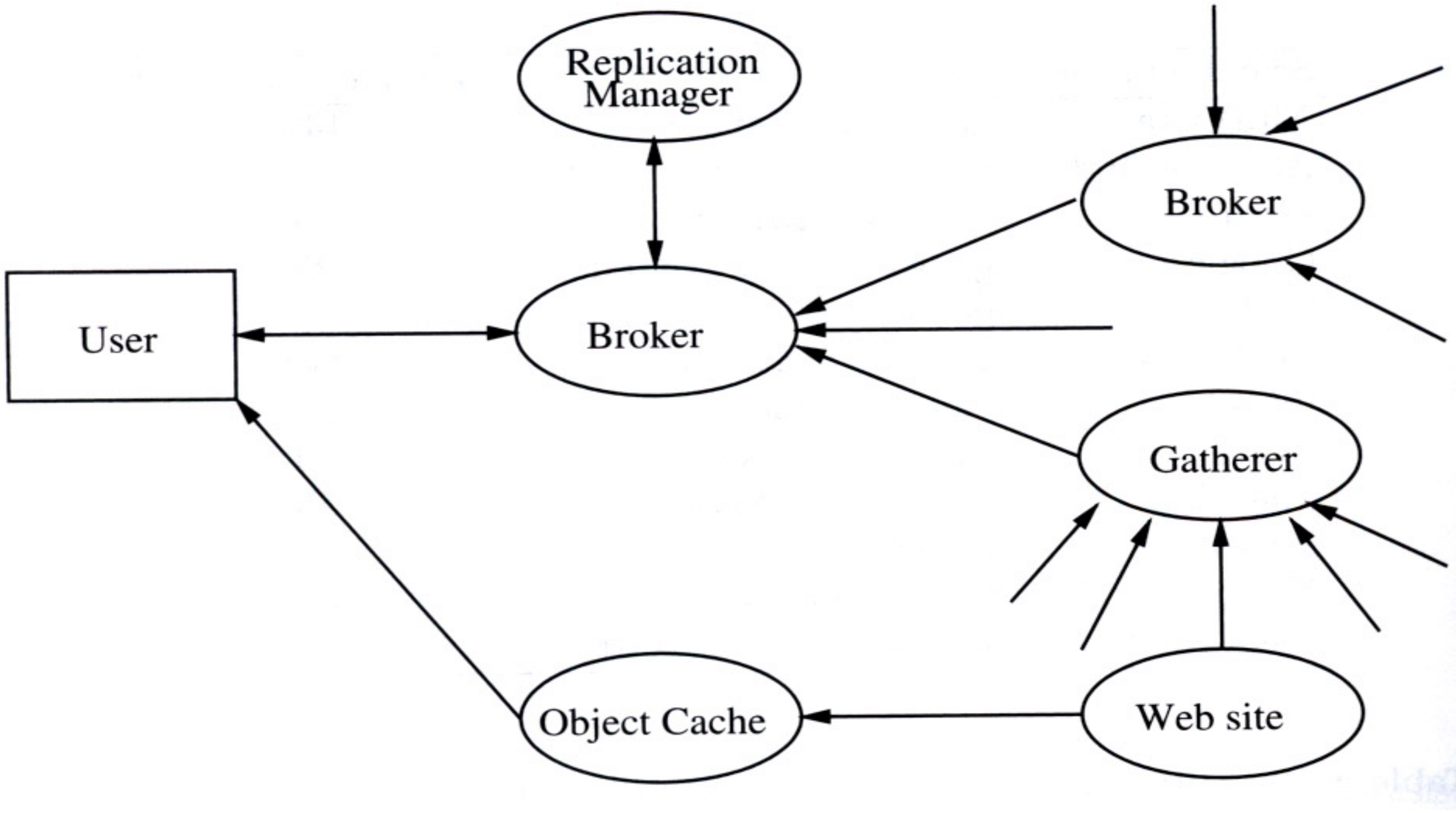
# Centralized Architecture (6)

- Other search engines
  - Ask Jeeves! (http://www.ask.com/)
    - Simulate an interview
  - DirectHit (http://www.directhit.com/)
    - Ranks the answer Web pages in order of popularity
  - Search Broker (http://webglimpse.org/sb/)
    - Specific topics
    - No longer maintained...
  - DejaNews (www.dejanews.com)
    - Searches USENET archives
    - Bought by Google – became groups.google.com

# Distributed Architecture

- Distributed architecture to gather and distribute data
  - E.g., Harvest
- Advantage
  - More efficient
- Disadvantage
  - Requires coordination of several Web servers
- Problems of crawler-indexer architecture
  - Web servers receive requests from different crawlers, increasing their load
  - Crawlers retrieve entire objects, but most of the content is discarded
  - Information is gathered independently by each crawler
    - No coordination

# Distributed Architecture (2)



# Distributed Architecture (3)

- Two elements in Harvest
  - **Gatherers**
    - Collect and extract indexing information from the Web servers
    - Gathering times are periodic
  - **Brokers**
    - Retrieve information from gatherers or other brokers
    - Update incrementally their indices
- Gatherers and brokers can communicate in flexible ways
  - From a gatherer to multiple brokers
  - Brokers to brokers

# Distributed Architecture (4)

- Other features of Harvest
  - Topic specific brokers in Harvest
    - Can avoid the generic indices
      - E.g., size of the vocabulary
  - Registration brokers
    - Allow other brokers to register information about gatherers and brokers
  - Object caches
    - Reduce the network and server load

# Distributed Architecture (5)

- About Harvest
  - Many Harvest applications
    - CIA, NASA, …
  - Public domain:
    - http://harvest.sourceforge.net/
  - Commercial versions
    - Netscape's Catalog Server
    - Network Appliances' cache

# User Interfaces

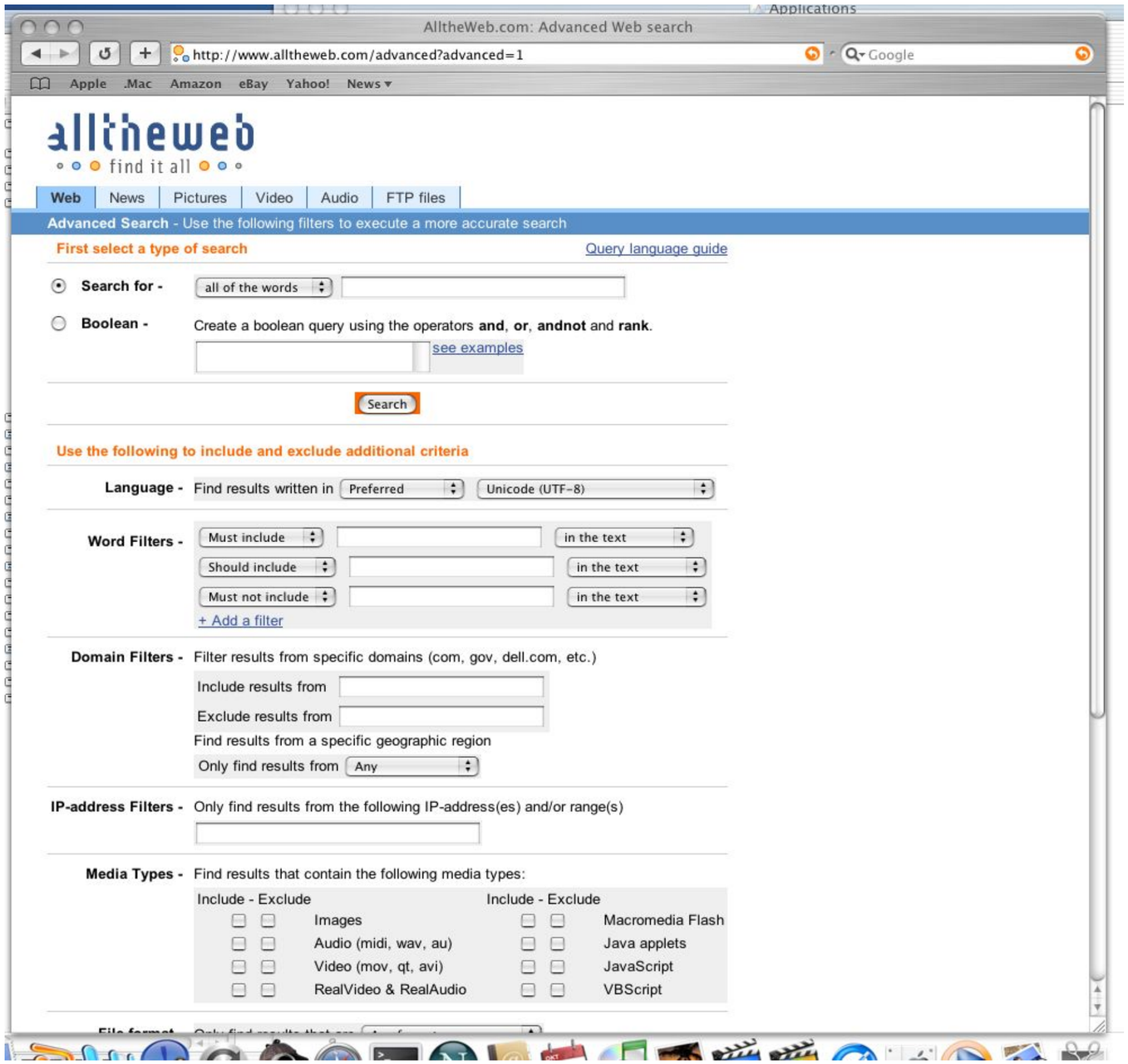
- Two things
  - Query interface
  - Answer interface

- Query Interface
  - The same word sequence in the query is regarded differently in different search engines
    - AltaVista: OR
    - Google: AND
  - Logical views of the text are different in different search engines
    - Stopwords, stemming, case sensitive

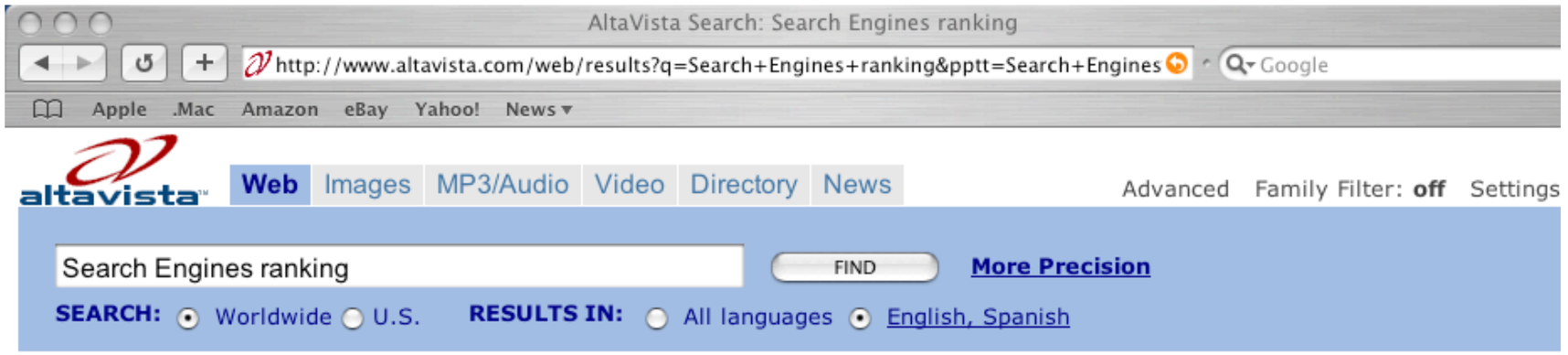
# User Interfaces (2)

- Complex queries
  - AltaVista
    - Boolean query
    - Range query
  - HotBot
    - Boolean (i.e., all, any)
    - Must contain, must not contain
    - Published date range
    - Page associated media (image, audio, VRML, …)
    - Location/domain (.edu, .com)
    - Page depth in a Web site
    - Word stemming
- NorthernLight
  - Words in title
  - Words in URL
  - Published date range
  - Web source
    - Journals, news, personal
  - Languages/Countries
  - subjects

# User interface (3)



# User interface (4)



# User interface (6)

## Avansert søk

Finn sider …

| | | Gjør dette direkte i søkefeltet: |
|---|---|---|
| med alle disse ordene: | IR | Skriv inn de viktige ordene: `golden retriever valp` |
| med nøyaktig dette ordet eller uttrykket: | | Sett eksakte ord i anførselstegn: `"rat terrier"` |
| med noen av disse ordene: | | Skriv inn `OR` mellom alle ordene du vil bruke: `miniatyr OR standard` |
| uten noen av disse ordene: | | Sett inn et minustegn rett før ord du ikke vil bruke: `-gnager, – "Jack Russell"` |
| med tall fra: | til | Sett to punktumer mellom tallene, og legg til en måleenhet: `10..35 lb, $300..$500, 2010..2011` |

Deretter kan du avgrense resultatene dine etter …

| | | |
|---|---|---|
| språk: | alle språk | Finn sider på det språket du velger. |
| område: | en hvilken som helst region | Finn sider som er publisert i et bestemt område. |
| siste oppdatering: | når som helst | Finn sider som er oppdatert innenfor tiden du oppgir. |
| nettsted eller domene: | | Søk på et bestemt nettsted (som f.eks. `wikipedia.org`), eller avgrens søket til et domene som for eksempel `.edu`, `.org` eller `.gov` |
| ord som vises: | hvor som helst på siden | Søk etter ord på hele siden, i sidens tittel eller i nettadressen, eller søk etter linker til siden du leter etter. |
| Sikkert Søk: | Vis de mest relevante resultatene | Gi beskjed til Sikkert Søk om seksuelt eksplisitt innhold skal filtreres. |
| filtype: | alle formater | Finn sider i det formatet du foretrekker. |
| bruksrettigheter: | ikke filtrert etter lisens | Finn sider du står fritt til å bruke selv. |

Avansert søk

Du kan også

Finn sider som ligner, eller som viser til, en nettadresse
Søk i sider du har besøkt
Bruk operatører i søkefeltet
Tilpass søkeinnstillingene

Google

# User Interfaces (6)

- Answer Interfaces
  - Usually top ten ranked Web pages
  - Associated with URL, size, date, part of content
  - Typically ordered by relevance
    - Some order by URL, or date
  - Option to find similar documents for each document
  - Can expand the query

# Ranking

- Use variations of Boolean or vector model
- Difficulties
  - Ranking just with indices not with text
  - Ranking algorithms are usually proprietary
  - Impossible to measure recall

# Ranking (2)

- Three ranking algorithms by [Yuwono and Lee]
  - **Boolean spread**
    - Based on (extended) Boolean model extended to pages in/out linked by the answer set
  - **Vector spread**
    - Same with vector model (tf-idf)
  - **Most-cited**
    - Based on the terms in pages pointing to the answer set
  - Vector model yielded the best
    - average precision was 70%

# Ranking (3)

- Ranking using hyperlink information
  - The number of incoming hyperlinks to a page represent the popularity or quality of the page
  - Three approaches
    - WebQuery
    - HITS
    - PageRank

- **WebQuery [Li]**
  - First take an answer set to a query
  - Rank the page by analyzing how the pages are connected
  - Extend the answer set by adding pages that are highly connected to the original set.

# WebQuery [Li]

- First take an answer set to a query
- Rank the page by analyzing how the pages are connected
- Extend the answer set by adding pages that are highly connected to the original set.

# HITS [Kleinberg]

- S: set of pages that are one link adjacent (in/out) **with the answer set**
- **Authorities**: pages that have high incoming links (in *S*)
- **Hubs**: pages that have high outgoing links (in *S*)
- Hub and authority value of a page *p*
  - $H(p) = \sum_{u \in S \mid p \to u} A(u)$
  - $\mathrm{A}(p) = \sum_{v \in S \mid v \to p} H(v)$
- Consider the link weight and page score
  - Link weight:
    - similarity between the surrounding content and the query
  - Page score
    - similarity between the page content and the query
- Result: better precision

# PageRank

- Developed and part of Google
- $q$: probability that a user randomly jump to the page
- $1 - q$: probability that a user visit the page following a link
- $L(a)$: number of outgoing links of page $a$
- $p_1, \ldots, p_n$: pages pointing page $a$
- Page rank

$$PR(a) = \frac{q}{T} + (1 - q) \sum_{i=1}^{n} \frac{PR(p_i)}{L(p_i)}$$

  - $T$ total # pages on the web graph, $q$ is typically 0.15
  - $PR(pi)$ is normalized by $L(pi)$

# Ranking (cont'd)

- How to make a page highly ranked by search engines
  - Include informative titles, headings, meta fields
  - Include good links
  - Don't repeat keywords
    - Some search engines penalize
  - Select terms that directly represent the subject

# Crawling the Web

- Start with a set of URLs (or popular URLs)
  - Extract other URLs recursively in breadth-first or depth-first
    - Can pre-determine the depth of a web site
  - Allow users to submit top Web site to be added to the initial set
  - If multiple crawlers are used, difficult to coordinate not to visit the same pages
    - Solution: partition the web by countries or internet names, assign robots by the partition

# Crawling the Web (2)

- How frequently the index is updated
  - How old is an index to a Web page
    - Varies a lot: One day to two months
    - Stars in the sky view
    - Percentage of invalid links: 2-9%
    - Usually put the index date for each page in the answer set
    - Some search engine learn the change frequency of a page and visit accordingly
    - Visit the popular pages (high incoming links) more frequently
    - State-of-art performance: traverse 10 million Web pages a day

# Crawling the Web (3)

- The order of traversing
  - Breadth-first
    - Good for web site that are structured by related topics
    - Coverage is wide but shallow
    - A web server is bombarded with many rapid requests
  - Depth-first
    - Narrow but deep traversal
  - Better pages first
    - e.g., using PageRank

# Crawling the Web (4)

- High network traffic problem caused by robots
  - A set of guidelines have been developed
  - A special file is place at the root of each Web server
    - Indicate the restrictions at that site
      - Some pages that should not be indexed
- Pages that crawlers cannot index
  - HTML with frames, image maps
  - Dynamically generated pages, password protected pages
  - Flash-based pages

# Indices

- Use variants of inverted file
  - Elements in the occurrence list are pages
- Size of the index
  - a short description of a Web page
    - Creation date, size, title, first lines
    - e.g., size of the description = 500 bytes (URL, the description) * 100 million pages = 50 Gb
  - State of art: index size is 30% of the text
    - 150 Gb for 100 million pages

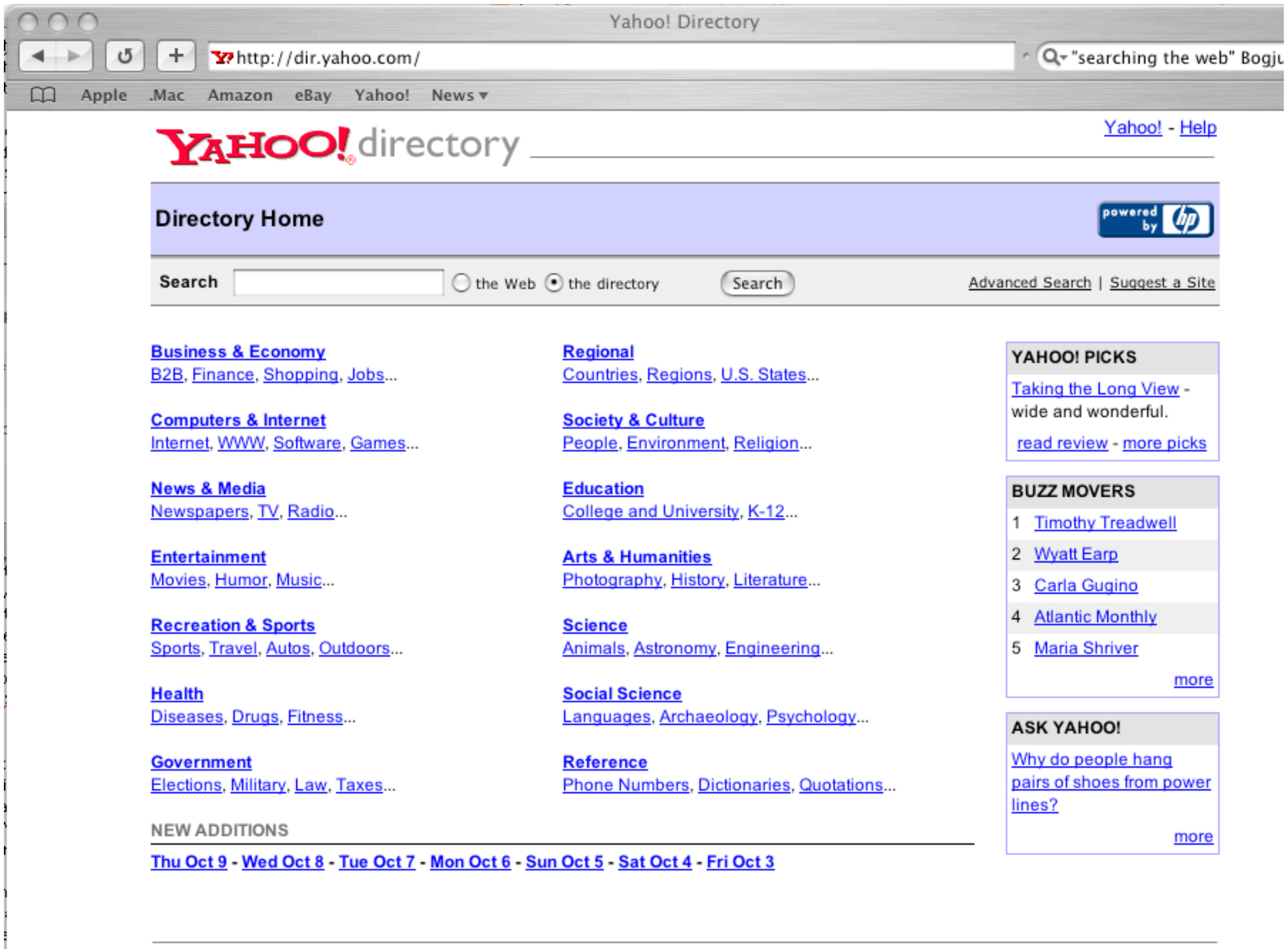
# Indices (2)

- Main memory
  - Usually keep the whole answer set although the initial is few
- Full inversion
  - Occurrences are word positions in a document
  - Costly but can easily support phrase and proximity queries
- Using the fixed size logical blocks
  - Reduce the size of the pointers
    - # of blocks < # pages
  - Reduce the number of pointers
    - Infrequent words tend to cluster in the same block
      - Used by Glimpse (Harvest)

# Web Directories

- Web coverage provided by directories
  - Less than 1% of all Web pages
  - Answers sets are usually much more relevant
- Examples of Web directory
  - Yahoo!: the oldest. 750,000 Web pages classified
  - eBLAST, LookSmart, Magellan, NewHoo
  - Some also provide the search engine

# Web Directories - Yahoo




**Yahoo! Directory**

| | |
|---|---|
| YAHOO! DIRECTORY | |
| **Owner** | Yahoo! |
| **Launched** | January 1994; 23 years ago |
| **Current status** | Defunct as of December 26th 2014 |

# Web Directories (2)

- Categories in Web directories
  - Hierarchical taxonomies that classify human knowledge
  - E.g., Yahoo!
- Pages are submitted to the Web directory
  - Then reviewed, accepted, classified
- Taxonomy as a acyclic graph
  - Instead of tree
  - There are cross reference

# Web Directories (3)

- Advantages of Web directories
  - The answer is useful in most cases
- Disadvantages
  - The classification is not specialized enough
  - Not all Web pages are classified
- Automatic classification
  - Using clustering
  - Use NLP to extract all relevant terms
- Manual classification
  - By a limited number of people

# Combining Searching and Browsing

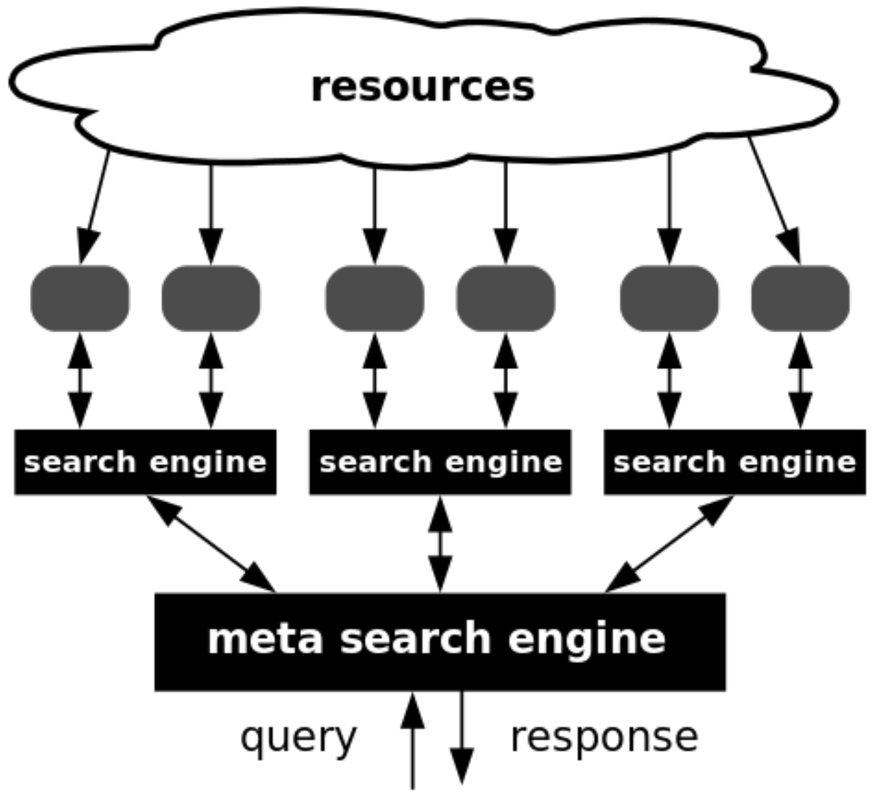
- Browsing
  - Following hyperlinks
- Searching
  - Running search engine
- WebGlimpse's approach
  - Attach a small search box to the bottom of every Web page
  - Can cache the neighbors

# Combining Searching and Browsing (2)

- Helpful tools
  - Add-ons to browsers
    - Alexa: current site's popularity, speed of access, overall quality. Suggest related sites
    - WebTaxi
  - Visualization tools for Web
    - Microsoft's SiteAnalyst, Dynamic Diagrams' MAPA, IBM's Mapuccino, …
  - Visualization tools for large answers

# Meta-searchers

- What is meta-searchers
  - Send a query to several search engines, Web directories, and other databases
  - Collect answers and unify them
- Examples
  - Metacrawler, SavvySearch
- Advantages
  - Many sources
  - User has the single interface



# User Problems

- User problems
  - Novice users don't know how to start and get better answer
  - Don't know the logical view of text used by the system
    - e.g., case sensitive or not
- Typos or variations of words
  - About 10-20% of matches are lost
  - Foreign names: 50% of matches are lost
- Boolean logic
  - Use AND or OR differently
    - e.g., when choosing between two things, user mean 'exclusive or'

# User Problems (2)

- Search engine problems
  - Slow; the answer is too large, not relevant, not always up to date
- Analysis on user query logs [1998]
  - Main purposes of query are research, leisure, business, and education
  - Most users don't care about advertising
  - 25% of users user single word in the query
  - Average query length: 2.35
  - 80% of users do not modify query
  - 85% of users look at only the first screen