CMS/CS/EE 144

Networks: Structure & Economics

Administrivia

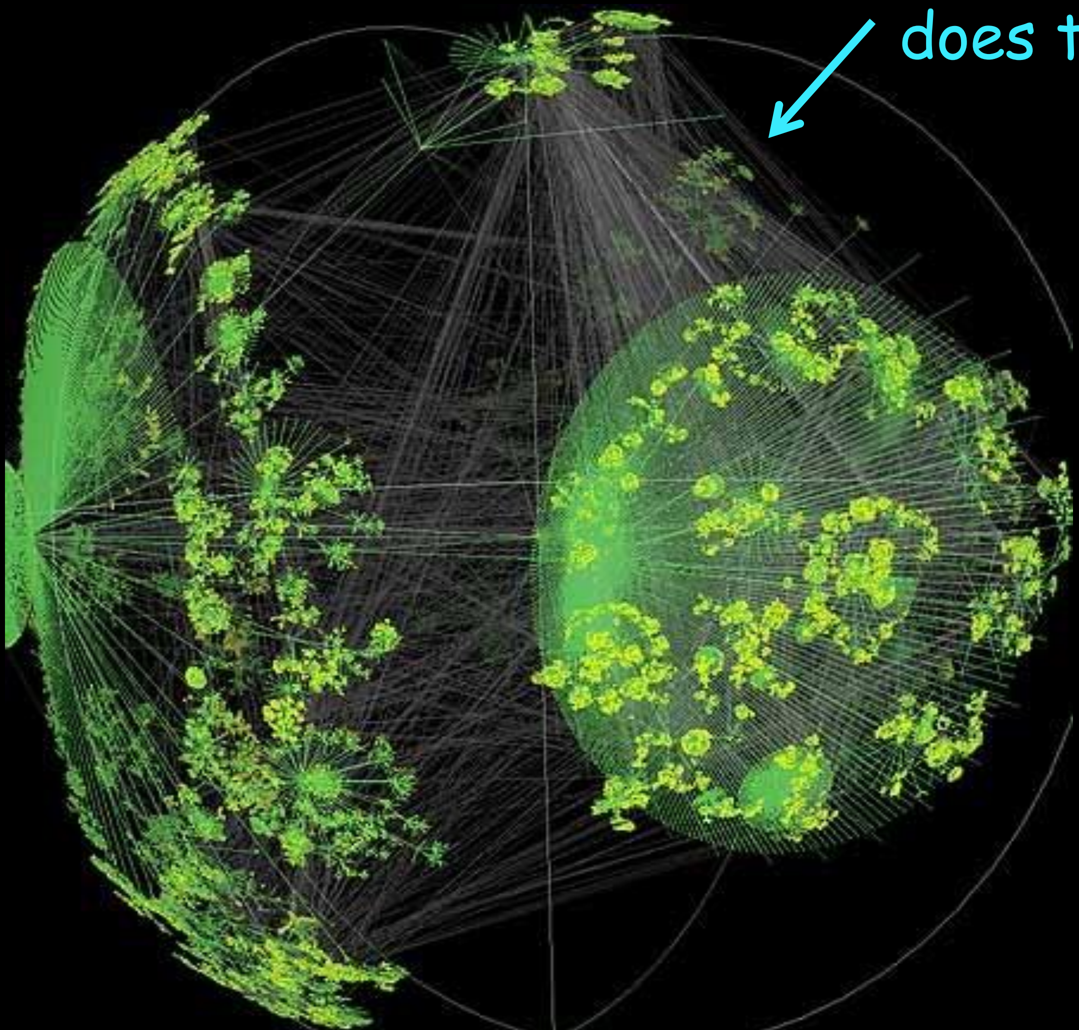
1) HW3 is due today
   → Grab solutions up front
2) HW4 is out today
3) Don't forget your blog posts!
4) Start thinking about projects…
5) Rankmaniac is coming up…

COURSE OUTLINE

1) <u>Understanding network structure</u>
2) Exploiting network structure
3) Network economics

RECAP

What structural properties does the web have?



Courtesy of Young Hyun, CAIDA

RECAP

Four "universal" properties of networks

1) A "giant" connected component
2) Small diameter
3) Heavy-tailed degree distribution
4) High clustering coefficient

Scientific question

What causes the emergence
of these properties?

RECAP

Four "universal" properties of networks

Indep. random choices – G(n,p) →

1) A "giant" connected component
2) Small diameter

"rich get righer" →

3) Heavy-tailed degree distribution
4) High clustering coefficient

RECAP

Four "universal" properties of networks

1) A "giant" connected component
2) Small diameter
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Correlated local connections combined w/ distance-dep. global connections

RECAP

Four "universal" properties of networks

1) A "giant" connected component
2) Small diameter
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Correlated local connections combined w/ distance-dep. global connections → 2), 4)

Note: These are only possible "explanations for these properties.

There is <u>much</u> more we could cover…

Many more properties…

-- weak ties vs strong ties

-- expansion

-- densifictation

-- shrinking diameter

-- power law eigenvalues

-- …

Many more models…

-- copying model

-- random web surfer

-- kronecker graphs

-- geometric random graphs

-- dot product graphs

-- …

COURSE OUTLINE

1) Understanding network structure
2) <u>Exploiting network structure</u>
3) Network economics

Where can network structure be exploited?

TODAY

<u>Search</u> … *the killer app for network structure*

High clustering both aids and inhibits spread of viruses (or information)

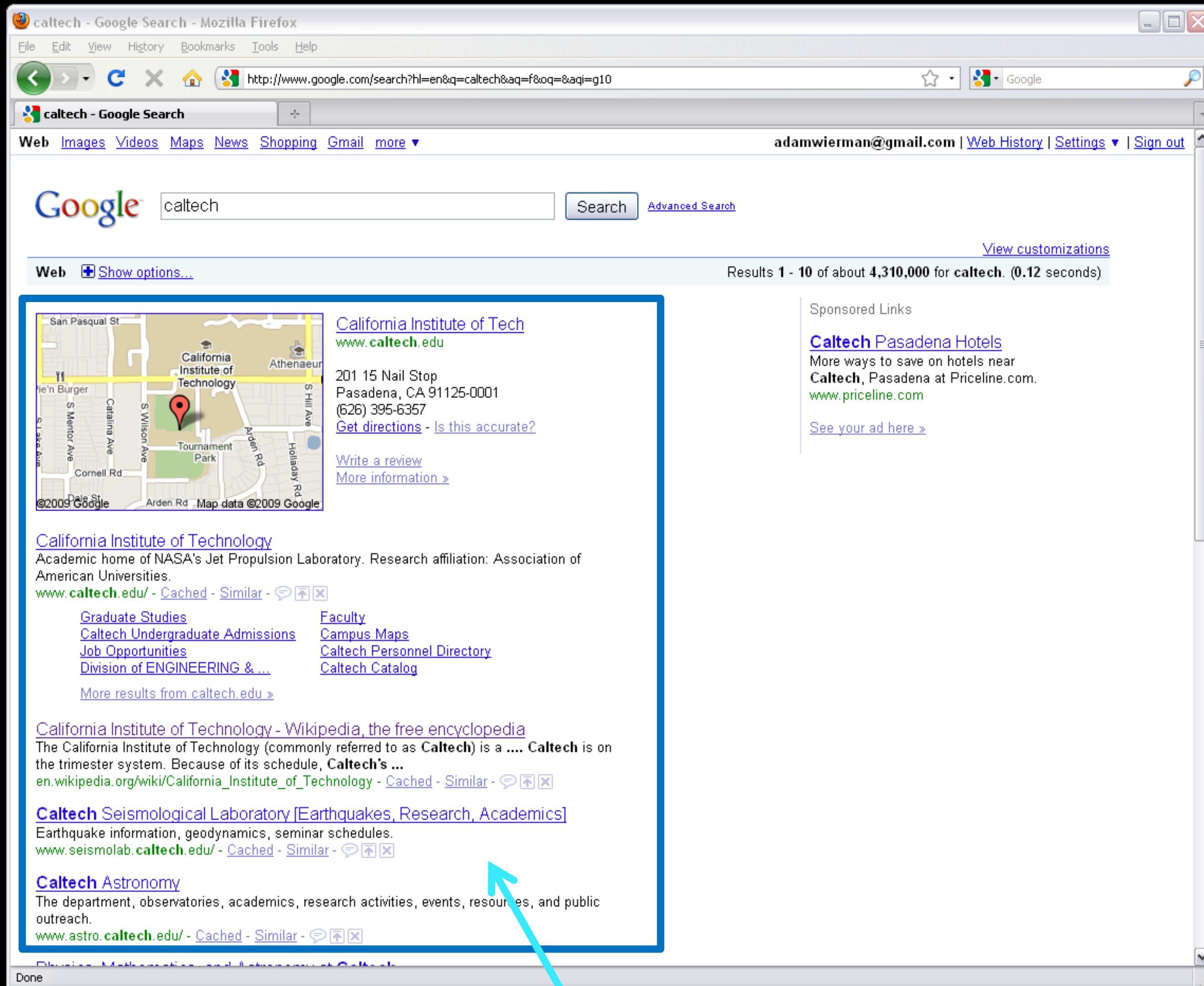
Heavy-tailed degrees make networks "robust yet fragile" to attack

Identifying "fake" accounts and suggesting friends in facebook

Community detection, controlling the spread of fake news, and many more…

TODAY

Search … *the killer app for network structure*



How does google choose search results?

The search landscape

>800 million searches per day

>$20 billion in paid search revenues

Goal: Make money

Challenges:

-- Need lots of users

-- Need to serve ads effectively

Later in course

Give users what they want (speed & quality)

Data centers!

Users want: to get results quickly and have the most relevant pages in the first few positions of the search

Challenges:

-- Scale of the web (~1 trillion pages indexed)

-- Needs to be really fast (the speed of a keystroke)

What goes into making a search engine run?

1) Maintain a huge index of web pages and links
2) Organize the info about the web to allow fast access
3) Choose the best pages for a given query
4) Display the results to the user

crawling

indexing

ranking

display

Four components of a search engine

1) Crawling
2) Indexing
3) Ranking
4) Display

Key to search engines → preprocessing

(speed is more important than space)

1) Crawling
2) Indexing
3) Ranking
4) Display

You did this on your homework!

Important issues you didn't consider:

1) Avoiding "spam" pages
2) Dynamic content – "hidden web"
3) Parallelism (maintaining lots of connections)
4) Freshness of the crawl
   → time between changes is heavy-tailed
5) Avoid causing DoS!

1) Crawling
2) Indexing
3) Ranking
4) Display

Preprocess database to allow efficient access for ranking

This is done by building an "inverted index"

→ For each word, maintain a list of every web page it appears on.

→ List points to compressed version of each page (~850 TB as of 2006)

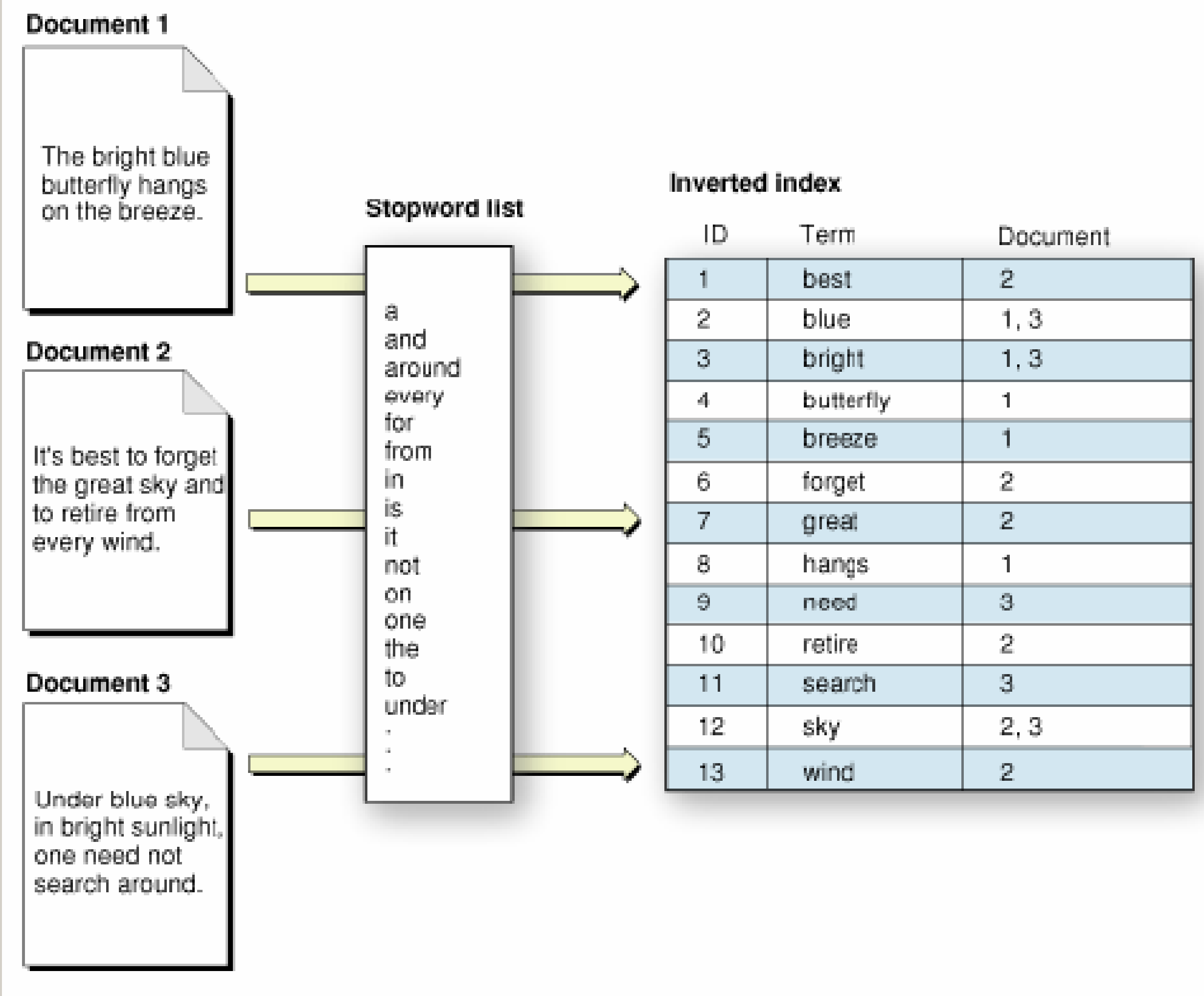


Image from http://developer.apple.com
/documentation/UserExperience/Conceptual/SearchKitConcepts/searchKit_basics/chapter_2_section_2.html

1) Crawling
2) Indexing
3) Ranking
4) Display

Details:

1) Omit common words, called "stop words"
2) "stem" the words (cats → cat, etc)

1) Crawling
2) Indexing
3) Ranking
4) Display

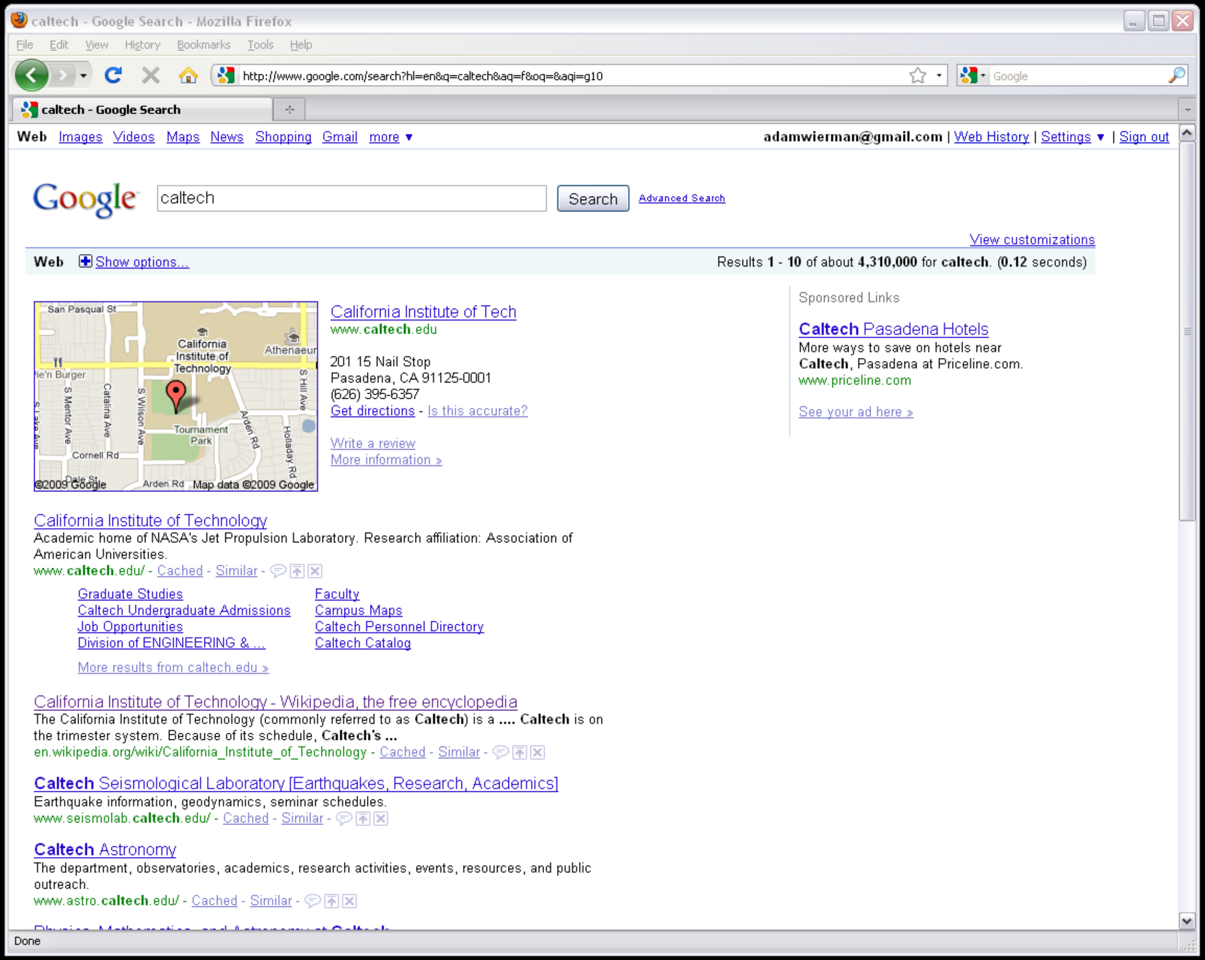
The heart of the search engine

…we'll come back to it

1) Crawling
2) Indexing
3) Ranking
4) Display

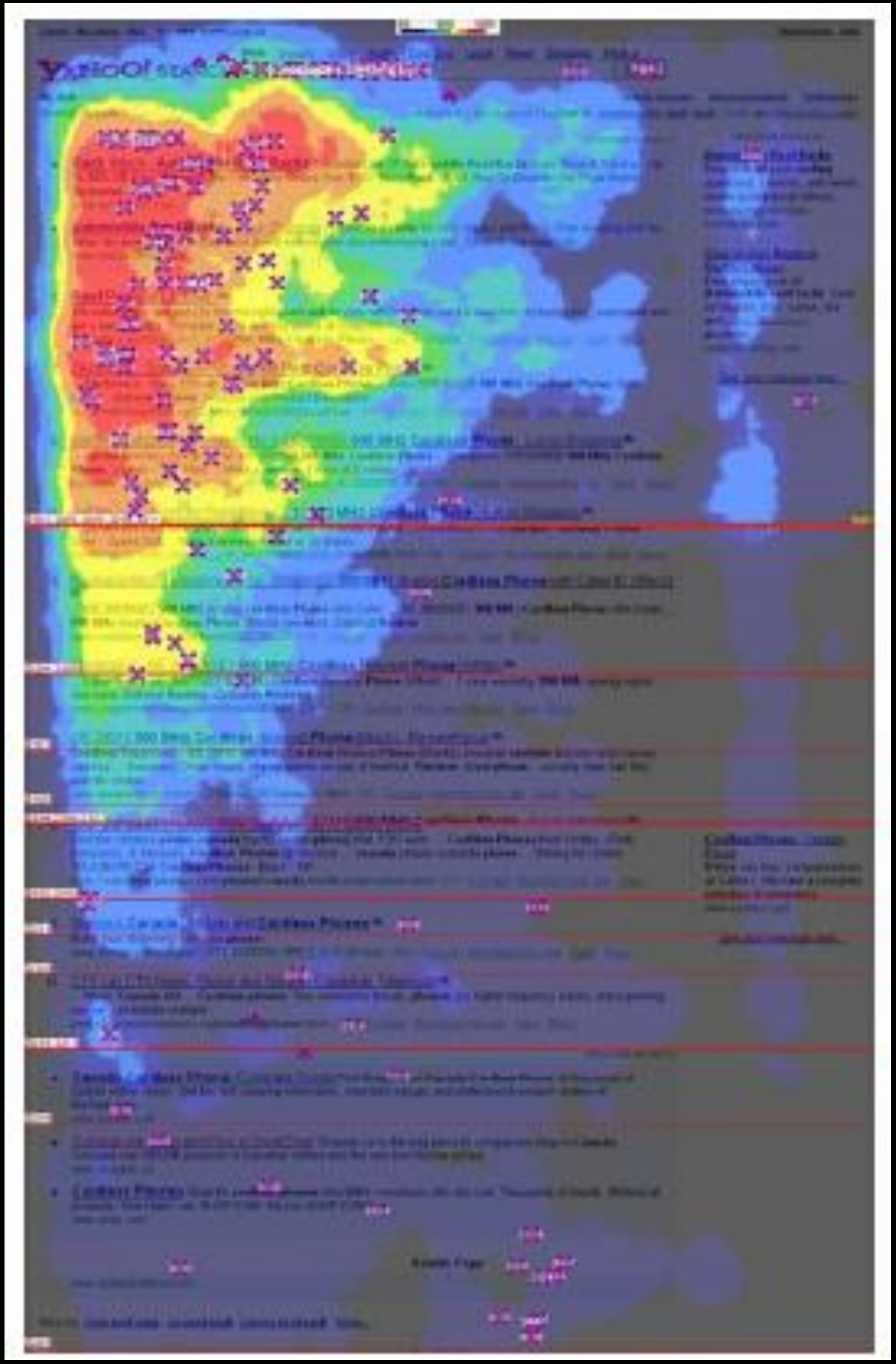
Present results to users

Seems boring and "done", but…

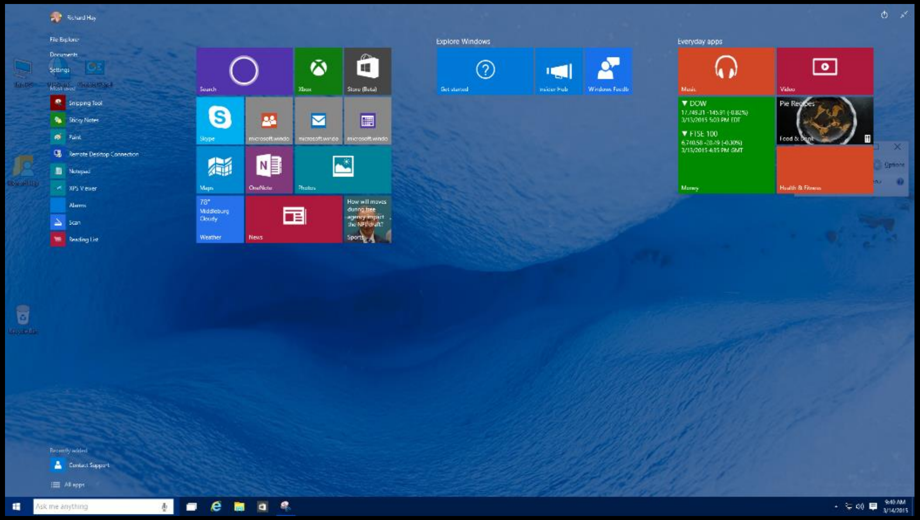


1) Crawling
2) Indexing
3) Ranking
4) Display

Seems boring and "done", but…



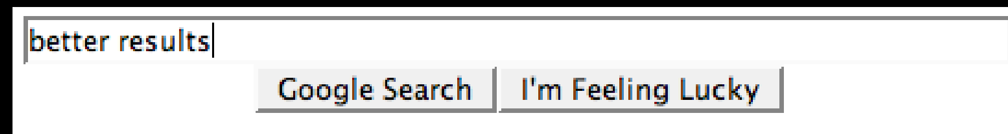
1) Crawling
2) Indexing
3) Ranking
4) Display



Seems boring and "done", but…

…it's on the verge of a big change

1) Crawling
2) Indexing
3) Ranking
4) Display



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…it’s on the verge of a big change

1) Crawling
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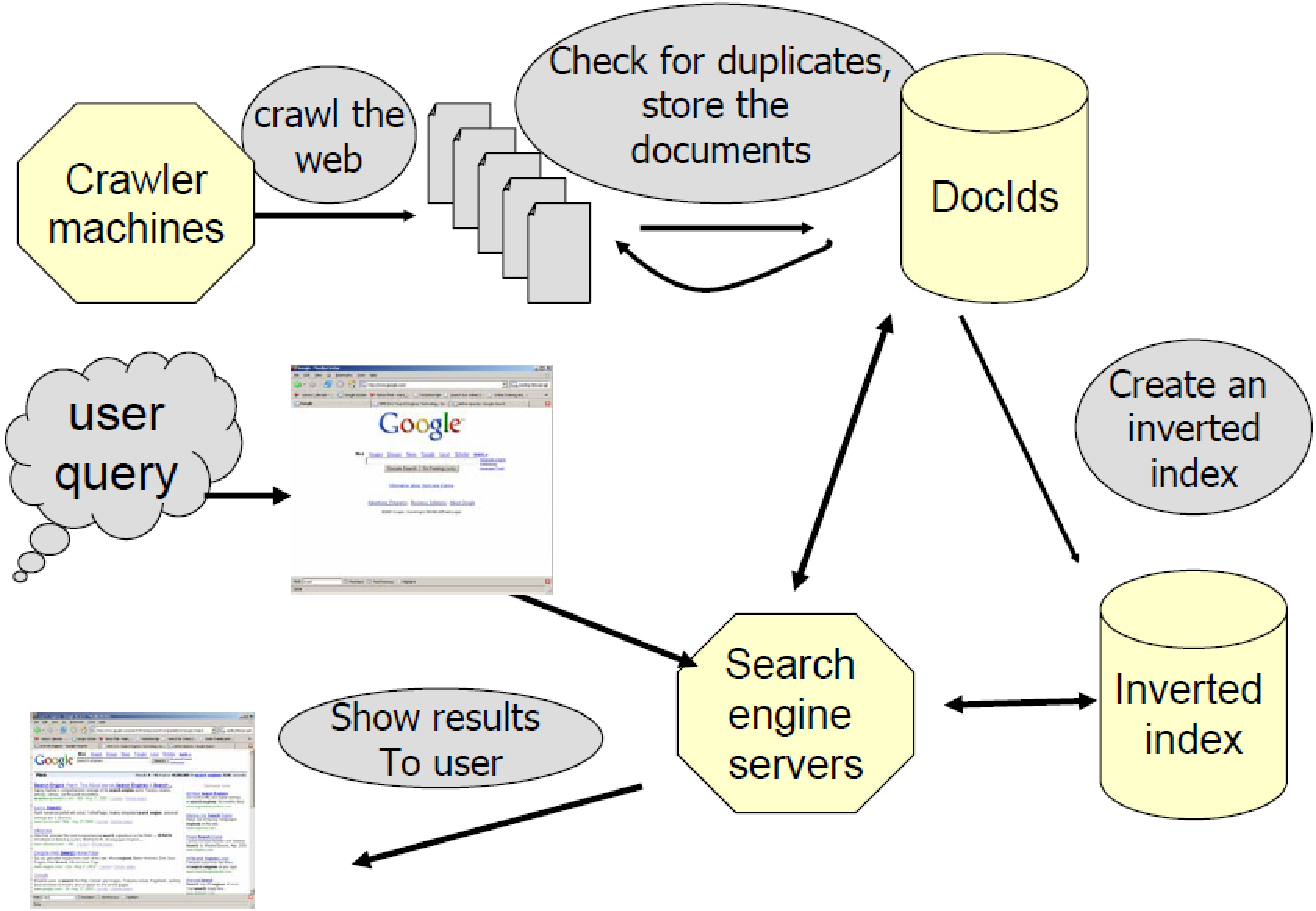
Typical search engine architecture



(from Marti Hearst)

1) Crawling
2) Indexing
3) Ranking
4) Display

The heart of the search engine

Goal: Given a query, place the most relevant pages in the first few positions of the search

Challenges:

-- Scale of the web (~1 trillion pages indexed)

-- Needs to be fast (<100msecs)

1) Crawling
2) Indexing
3) Ranking
4) Display

The heart of the search engine

Question: How do we solve this?

It's a machine learning problem!
Measure ~20(?) features for each page and then use these to predict relevance

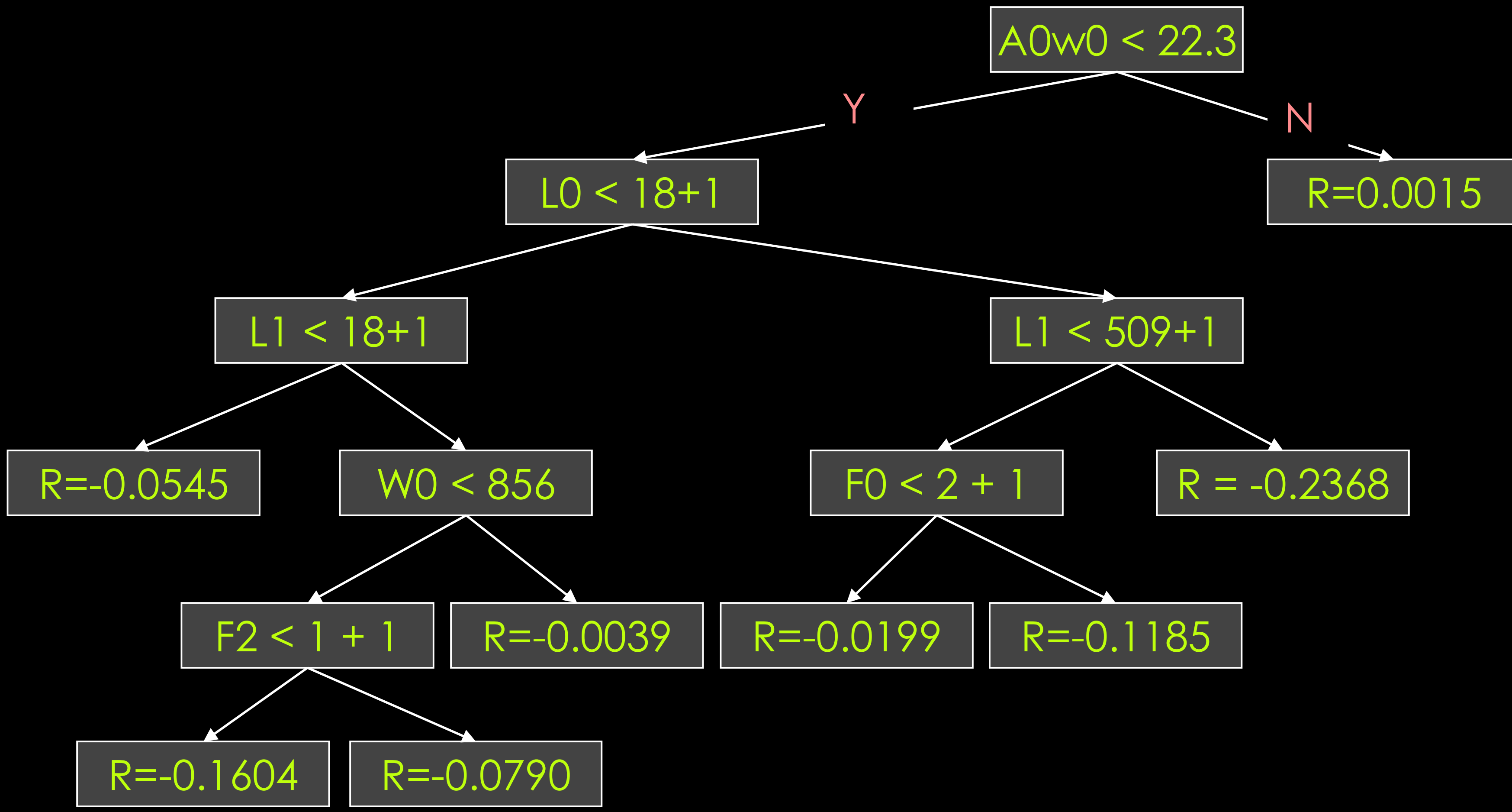
Input:

-- large training set
-- data for each feature

Output

-- ranking function / decision tree

Decision tree example
(From Jan Pederson of Yahoo)



Input:

-- large training set
-- data for each feature

Output:

-- ranking function / decision tree

Key:

this allows rapid, ongoing development

-- adjust features
-- test new features

Question: What features do you think they use?

- Frequency of matching query words in the page
- Proximity of matching words to one another
- Location of terms within the page
- Location of terms within tags e.g. <title>, <h1>, link text, Body text
- Anchor text on pages pointing to this one
- Frequency of terms on the page and in general
- Click-through analysis: how often the page is clicked on
- How “fresh” is the page
- Graph structure – how “important” the page is
- Page load time

Question: Which can be precomputed?

Which are query specific?

Question: What features do you think they use?

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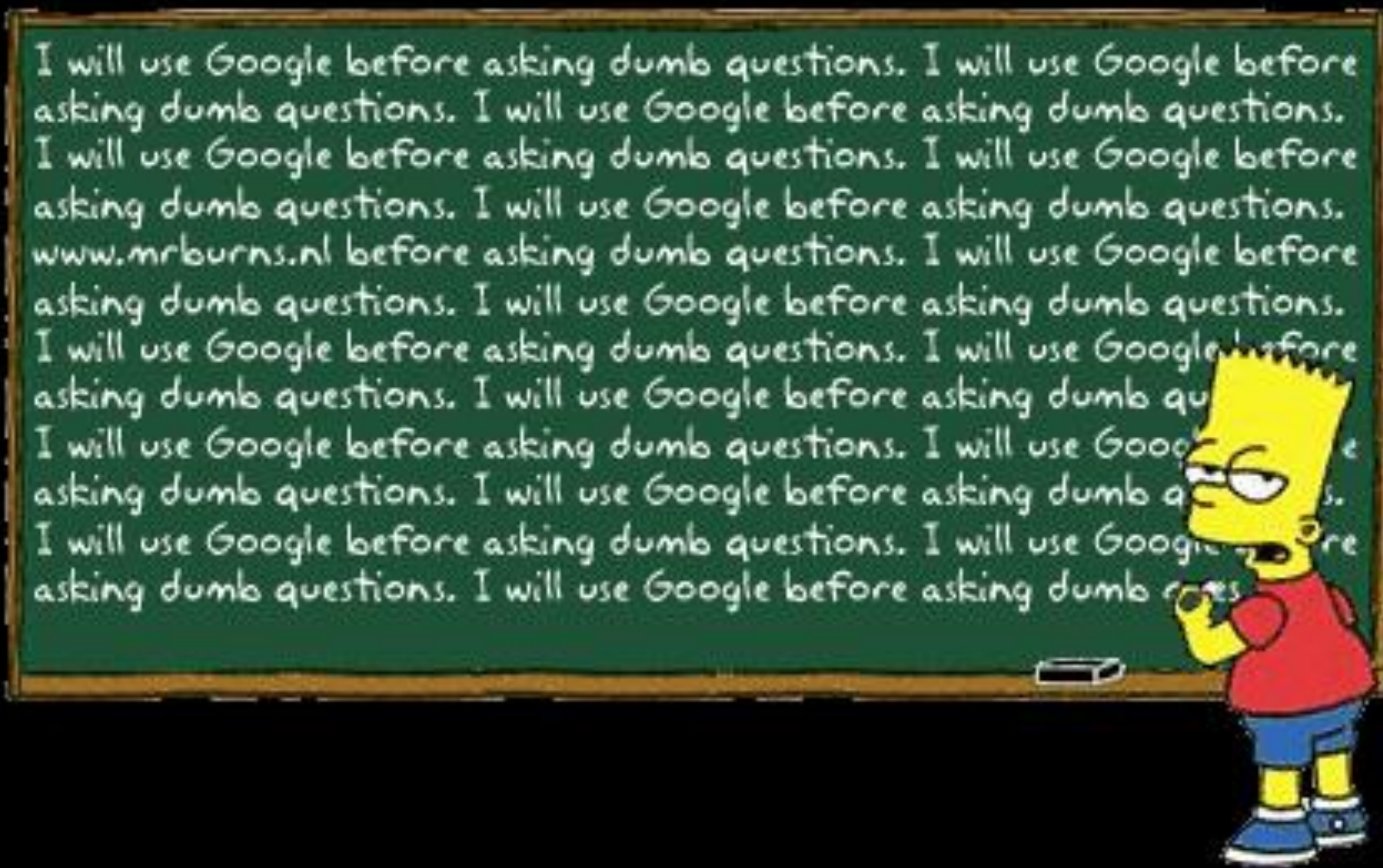
Key realization of google → Graph structure is helpful

SEARCH BEFORE GOOGLE

Use search engine X to search for X, and only 1 would even return a link to itself on the first page!

SEARCH AFTER GOOGLE



The idea:

Use graph structure to tell you which pages are important – "pagerank"

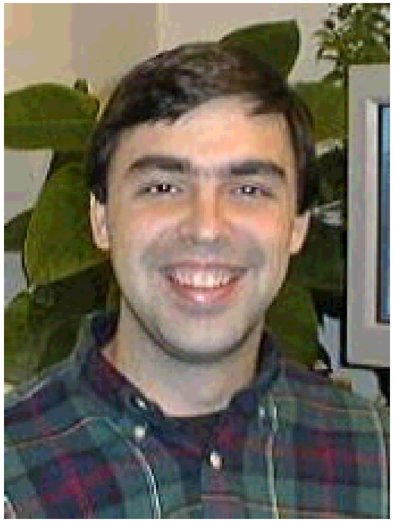
→There were a handful of related measures floating around academia in CS

[Marchiori 97] [Spertus 97] [Kleinberg 98] [Page 98]

In social networks related ideas had been studied since the 50s, but I don't think the CS folks knew…

Brin & Page built a large scale prototype

Sergey Brin received his B.S. degree in mathematics and computer science from the University of Maryland at College Park in 1993. Currently, he is a Ph.D. candidate in computer science at Stanford University where he received his M.S. in 1995. He is a recipient of a National Science Foundation Graduate Fellowship. His research interests include search engines, information extraction from unstructured sources, and data mining of large text collections and scientific data.



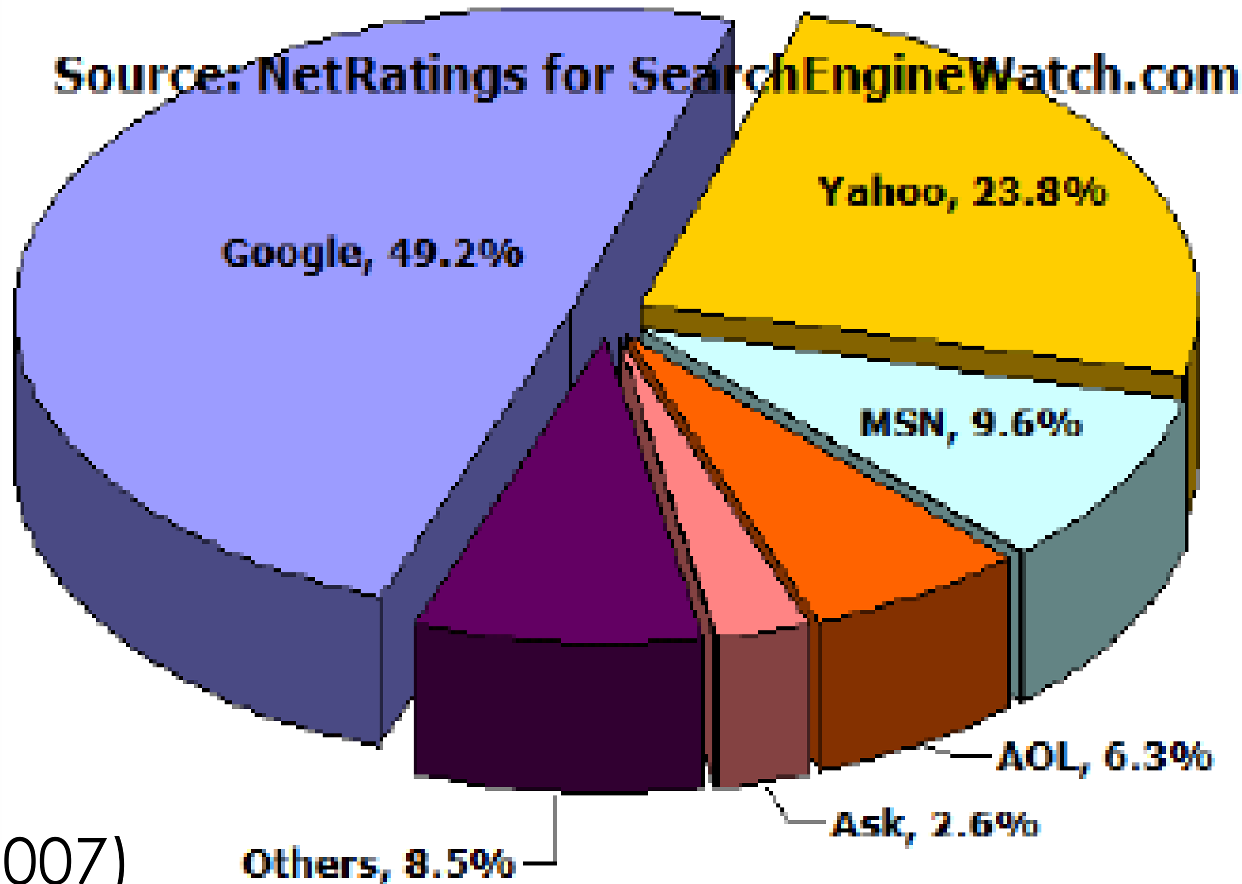
Lawrence Page was born in East Lansing, Michigan, and received a B.S.E. in Computer Engineering at the University of Michigan Ann Arbor in 1995. He is currently a Ph.D. candidate in Computer Science at Stanford University. Some of his research interests include the link structure of the web, human computer interaction, search engines, scalability of information access interfaces, and personal data mining.

Brin & Page didn’t want to leave grad school,

BUT

they shopped the idea around for $1 million
(including to Yahoo!) and no one bought!

…so they dropped out and started google.


Source: NetRatings for SearchEngineWatch.com
Google, 49.2%
Yahoo, 23.8%
MSN, 9.6%
AOL, 6.3%
Ask, 2.6%
Others, 8.5%

(2007)

TODAY

Google: 75%

Baidu: 10%

Bing: 8%

Yahoo: 5%

What is pagerank?

Back to the big picture

Back to the big picture

Ranking uses

- Frequency of matching query words in the page
- Proximity of matching words to one another
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pagerank

Depends on heavy-tailed degrees, high clustering, small diameter to have

-- large distinctions in ranks
-- fast convergence of calculation

Back to the big picture

Four components of a search engine

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2) Indexing
3) Ranking
4) Display

Depends on large giant component, heavy-tailed degrees, small diameter

Back to the big picture

Search engine goal: Make money

Challenges:

-- Need lots of users

-- Need to serve ads effectively

Later in course

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they want (speed & quality)

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