

DEPARTMENT OF  
COMPUTER SCIENCE

THE NEW AGE OF DISCOVERY

# What Is Computing Today? Deconstruction

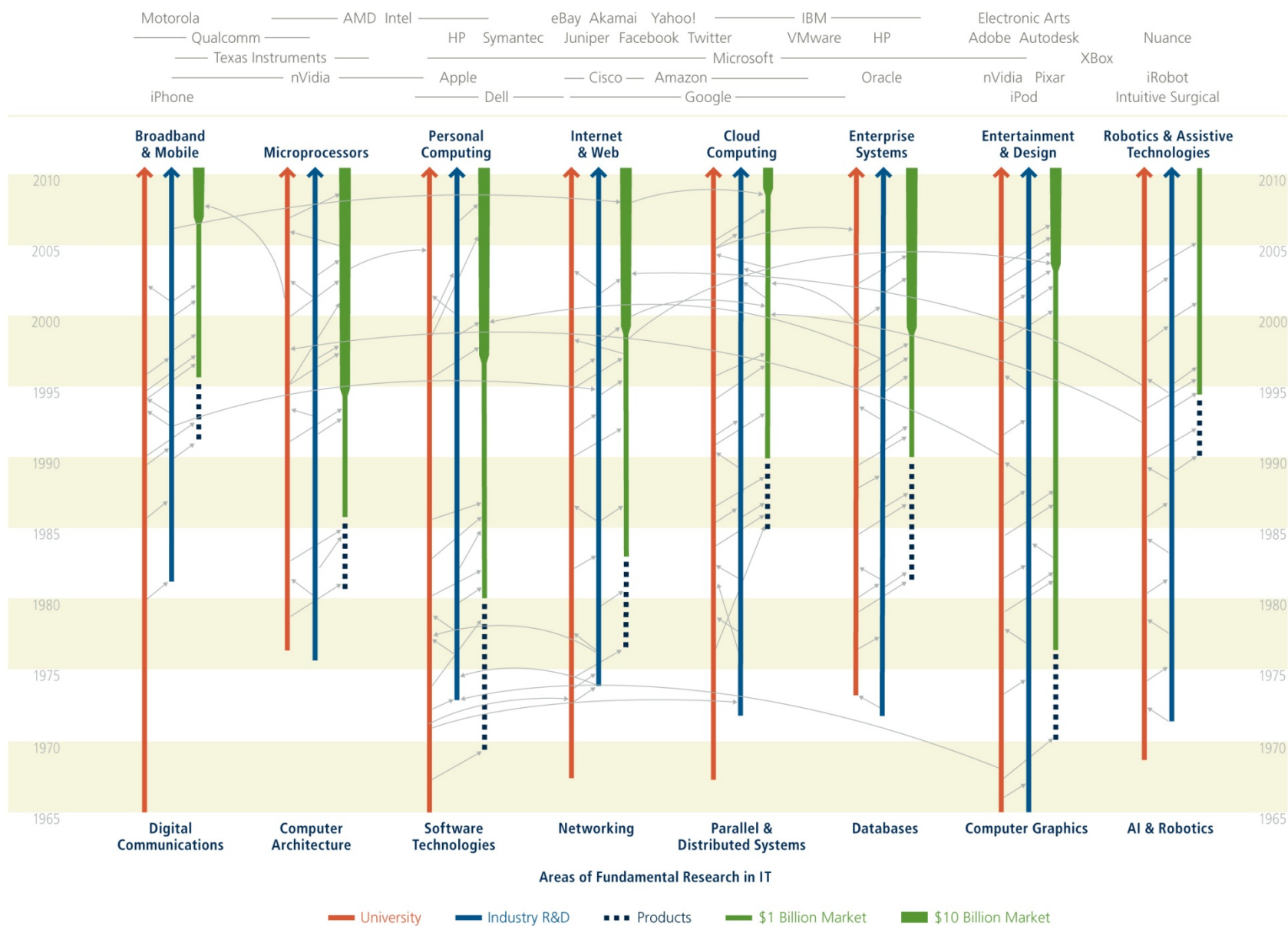
Gregory D. Hager  
Professor and Chair

JOHNS HOPKINS  
UNIVERSITY  
WHITING SCHOOL OF ENGINEERING

# Questions

- How does “stuff work” and how did it come to be?
- What are the basic research areas of CS that impacted it?
- What are commercial needs drove it?
- How has that “stuff” changed with time?

## IT Sectors With Large Economic Impact



2012 NITRD update by PCAST



# Some Background Information

- IT is around 1T\$\* of US economy (itself 18T\$ GDP)
  - **Apple Inc. (Nasdaq: AAPL), (560B/30B)**
  - Exxon Mobil Corporation (NYSE: XOM),
  - **Google Inc (Nasdaq: GOOG), (358B /12B)**
  - **Microsoft Corporation (Nasdaq: MSFT), (344B/20B)**
  - Berkshire Hathaway Inc. (NYSE: BRK.B),
  - Wal-Mart Stores, Inc. (NYSE: WMT),
  - Johnson & Johnson (NYSE: JNJ),
  - General Electric Company (NYSE: GE),
  - Chevron Corporation (NYSE: CVX)
  - Wells Fargo & Co (NYSE: WFC)

\*Atkinson, R. D., & Stewart, L. A. (2013). Just the FACTS:

The Economic Benefits of Information and Communications Technologies <sup>4</sup>



# Deconstructing a Search Query



## Challenges in Building Large-Scale Information Retrieval Systems

Jeff Dean  
Google Fellow  
[jeff@google.com](mailto:jeff@google.com)

Credits to material used from  
[static.googleusercontent.com/media/research.google.com/en/us/people/jeff/WSDM09-keynote.pdf](http://static.googleusercontent.com/media/research.google.com/en/us/people/jeff/WSDM09-keynote.pdf)

# The Origins of PageRank

- Stanford WebBase project (1996 - 1999)  
<http://dbpubs.stanford.edu:8091/~testbed/doc2/WebBase/>  
<http://dbpubs.stanford.edu:8091/diglib/>
- funded by NSF through DLI I  
<http://www.dli2.nsf.gov/dlione/>

“The Initiative's focus is to dramatically advance the means to collect, store, and organize information in digital forms, and make it available for searching, retrieval, and processing via communication networks -- all in user-friendly ways.” quote from the DLI I website

Page, Lawrence, Sergey Brin, Rajeev Motwani, and Terry Winograd. The PageRank citation ranking: Bringing order to the web. (1999).

Brin, Sergey, and Lawrence Page. The anatomy of a large-scale hypertextual Web search engine. *Computer networks and ISDN systems* 30, no. 1 (1998): 107-117.

# Some Other Research Ideas

- Cache (M. Wilkes, 1965, Cambridge)
- The internet (Cerf, Kahn, 1969, ARPA)
- The Web and HTML (T. Berners-Lee, 1989, CERN)
- PageRank (Brin, Page, Motwani, Winograd, Stanford, 1997)
- SIFT Image Features (Lowe, UBC, 1999)
- Hadoop (Cutting, Cafarella, Yahoo/UW, 2005)
- Deep Learning (Hinton+others, Toronto+others, ??)
  - GPUs ....

# What Is a Search Query?

Google's answer

11/11/14

what is a search query

Web

Images

Maps

News

Videos

More ▾

Search tools

About 11,500,000 results (0.32 seconds)

A **web search query** is a **query** that a user enters into a **web search engine** to satisfy his or her information needs. **Web search queries** are distinctive in that they are often plain text or hypertext with optional **search-directives** (such as "and"/"or" with "-" to exclude).

[Web search query - Wikipedia, the free encyclopedia](http://en.wikipedia.org/wiki/Web_search_query)  
en.wikipedia.org/wiki/Web\_search\_query Wikipedia ▾

Feedback

[Web search query - Wikipedia, the free encyclopedia](http://en.wikipedia.org/wiki/Web_search_query)  
en.wikipedia.org/wiki/Web\_search\_query Wikipedia ▾

A **web search query** is a query that a user enters into a **web search engine** to satisfy his or her information needs. **Web search queries** are distinctive in that they ...

[Types](#) - [Characteristics](#) - [Structured queries](#) - [See also](#)

[Keywords vs. Search Queries: What's the Difference ...](#)

[www.wordstream.com/blog/ws/2011/05/25/keywords-vs-search-queries](http://www.wordstream.com/blog/ws/2011/05/25/keywords-vs-search-queries) ▾

May 25, 2011 - A **search query**, the actual word or string of words that a **search engine** user types into the **search box**, is the real-world application of a **keyword** – it may be misspelled, out of order or have other words tacked on to it, or conversely it might be identical to the **keyword**.

[Search Queries: The 3 Types of Search Query & How to ...](#)

[www.wordstream.com/blog/ws/2012/12/.../three-types-of-search-queries](http://www.wordstream.com/blog/ws/2012/12/.../three-types-of-search-queries) ▾

Dec 10, 2012 - When someone enters an informational **search query** into **Google** or another **search engine**, they're looking for information – hence the name. They are probably not looking for a specific site, as in a **navigational query**, and they are not looking to make a commercial transaction.

# What Is a Search Query?

Bing's  
answer

The screenshot shows a Bing search interface. At the top, the search bar contains the text "what is a search query". Below the search bar, there are tabs for "Web", "Images", "Videos", "Maps", "News", and "More". The "Web" tab is selected. To the right of the tabs, there is a page number "1" and a user profile icon labeled "Greg". Below the tabs, the search results are displayed. The first result is from Wikipedia, titled "Web search query - Wikipedia. the free encyclopedia". The second result is from Answers.com, titled "What is a query - Answers.com". Below these results, there is a section for "Related searches for what is a search query" with links like "Deschutes County Web Query", "What's a Query", "The Definition of Query", "Searchers Query", "Google Search query", and "What is Querying". There is also an "Ads related to what is a search query" section with links like "People Search-Free Search" and "People Search-Search Free".

what is a search query

Web Images Videos Maps News More

1 Greg

48,300,000 RESULTS Any time

[Web search query - Wikipedia. the free encyclopedia](#)  
[en.wikipedia.org/wiki/Web\\_search\\_query](http://en.wikipedia.org/wiki/Web_search_query)  
A web **search query** is a **query** that a user enters into a web **search** engine to satisfy his or her information needs. Web **search queries** are distinctive in that they are ...  
[Types](#) · [Characteristics](#) · [Structured queries](#)

[What is a query - Answers.com](#)  
[www.answers.com](http://www.answers.com) › ... › [Technology](#) › [Computers](#) › [Computer Terminology](#)  
**Queries** allow you to decide what fields or ... A web **query** is simply the process of searching for information on the internet using **search** engines like ...

Related searches for **what is a search query**  
[Deschutes County Web Query](#) [What's a Query](#)  
[The Definition of Query](#) [Searchers Query](#)  
[Google Search query](#) [What is Querying](#)

[Query Definition - Computer](#)  
[www.techterms.com/definition/query](http://www.techterms.com/definition/query)  
Daily **Definition**; Random Term; Browse by Tech Factor; 1 2 3 4 5 6 7 8 9 10 ... One type of **query**, which many people perform multiple times a day, is a **search query**.

[Search queries - Webmaster Tools Help - Google Support](#)  
<https://support.google.com/webmasters/answer/35252?hl=en>  
**Search queries** See the top **searches** that bring users to your site

[What is a Search Engine Query ? - Definition from ...](#)  
[www.techopedia.com/definition/28064](http://www.techopedia.com/definition/28064)  
A **search engine query** is a request for information that is made using a **search engine**. Every time a user puts a string of characters in a **search engine** and presses ...

[What is a database query - Answers.com](#)  
[www.answers.com](http://www.answers.com) › ... › [Computer Programming](#) › [Database Programming](#)  
A database **query** is a piece of code (a **query**) ... The term '**query**' means to **search**, to question, or to find. When you **query** a database, ...

Related searches  
[Deschutes County Web Query](#)  
[The Definition of Query](#)  
[Google Search query](#)  
[What's a Query](#)  
[Searchers Query](#)  
[What is Querying](#)  
[Top Search Queries](#)  
[Deschutes County Recorder](#)

Ads related to what is a search query  
[People Search-Free Search](#)  
[www.usa-people-search.com](http://www.usa-people-search.com)  
**Search** Free for Anyone in the US! Get Phone, Address, Names & More.  
[People Search-Search Free](#)  
[www.intelius.com/PeopleSearch](http://www.intelius.com/PeopleSearch)  
6,000+ followers on Twitter  
1) Enter Any Name & **Search** Free! 2) Get Phone, Address, Age & More.  
[Search Query](#)  
[www.calibex.com](http://www.calibex.com)  
Cheap Prices and Huge Selection. **Search Query** on Sale!  
[See your ad here »](#)

# What Is a Search Query?

Yahoo's  
answer

The screenshot shows the Yahoo search interface. At the top, there's a navigation bar with links: Home, Mail, News, Sports, Finance, Weather, Games, Groups, Answers, Screen, Flickr, Mobile, and More. Below this is a search bar containing the text "what is a search query" and a "Search" button. To the right of the search bar are links for "Sign In" and "Mail".

On the left side, there's a sidebar with categories: Web, Images, Video, News, Local, Shopping, Maps, and More. Below these are filters for "Anytime", "Past day", "Past week", and "Past month".

The main content area displays search results. The first result is from Wikipedia: "Web search query - Wikipedia, the free encyclopedia" with the URL "en.wikipedia.org/wiki/Web\_search\_query" and a "Cached" label. The snippet reads: "A web **search query** is a **query** that a user enters into a web **search** engine to satisfy his or her information needs. Web **search queries** are distinctive in that they are ...".

The second result is from Answers.com: "What is a query - Answers.com" with the URL "www.answers.com" and a breadcrumb trail "Computers > Computer Terminology". The snippet reads: "Queries allow you to decide what fields or ... A web **query** is simply the process of searching for information on the internet using **search** engines like ...".

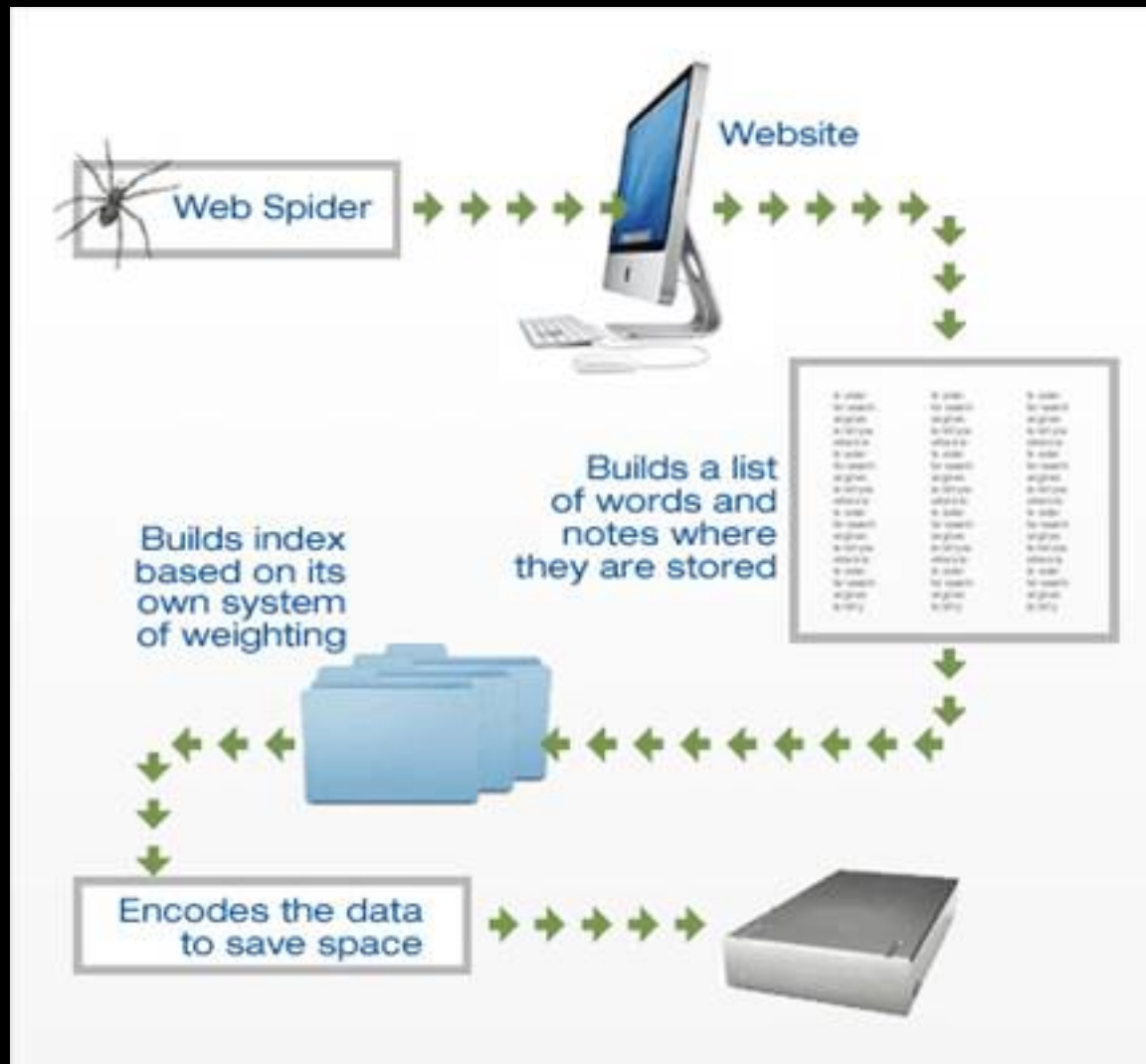
The third result is from Google Support: "Search queries - Webmaster Tools Help - Google Support" with the URL "support.google.com/webmasters/answer/35252?hl=en" and a "Cached" label. The snippet reads: "Search queries See the top **searches** that bring users to your site".

The fourth result is a Yahoo Answers question: "What is a search query - Yahoo Answers Results". It lists three questions with their respective answer counts:

- "When searching the internet, **what is a query** ?" (2 answers): "It's a request for some asset on a remote server. Basically when you click a link, or type a word(s) into the search bar on the browser, it then compiles a 'packet' which 'says' where it comes from (the 'source'), where it's going (the...".
- "What is a query ? or a search expression? are they the same?" (1 answer): "A query is anything typed into a web page and submitted. The term usually appears on web pages with search boxes, because that's one of the most common uses of queries. A search expression is a set of search terms. As far as most users are...".
- "What is the best way to post a search query on the Internet ?" (7 answers): "http://johnny.ihackstuff.com/index.php?module=prodreviews this will give you tips to getting narrowed responses from www.google.com, i dont know about yahoo os msn".

At the bottom of the results, it says "17285 related questions".

# It All Starts With a Spider



<http://programming4.us/website/15366.aspx>

# Inverted Index

For example, let's say we have two documents, each with a `content` field containing:

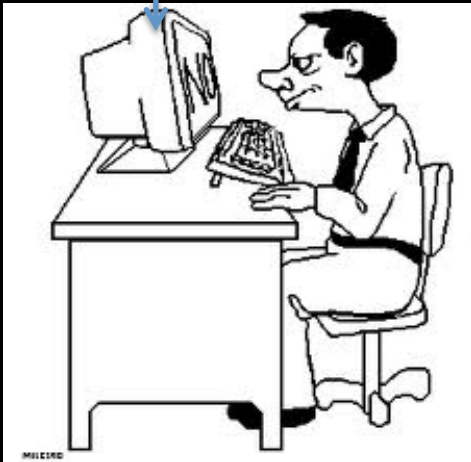
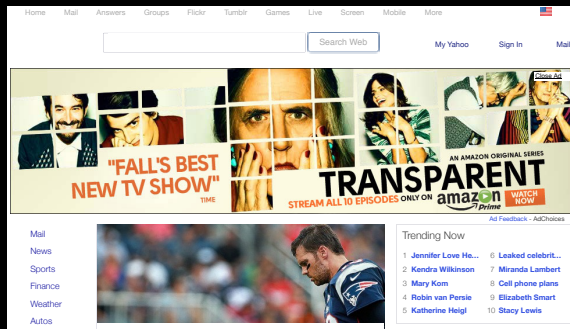
1. "The quick brown fox jumped over the lazy dog"
2. "Quick brown foxes leap over lazy dogs in summer"

To create an inverted index, we first split the `content` field of each document into separate words (which we call *terms* or *tokens*), create a sorted list of all the unique terms, then list in which document each term appears. The result looks something like this:

Term	Doc_1	Doc_2
Quick		X
The	X	
brown	X	X
dog	X	
dogs		X
fox	X	
foxes		X
in		X
jumped	X	
lazy	X	X
leap		X
over	X	X
quick	X	
summer		X
the	X	



# Browser to Computer to Internet to Search Engine to Cloud



# Then We Need Horsepower ...

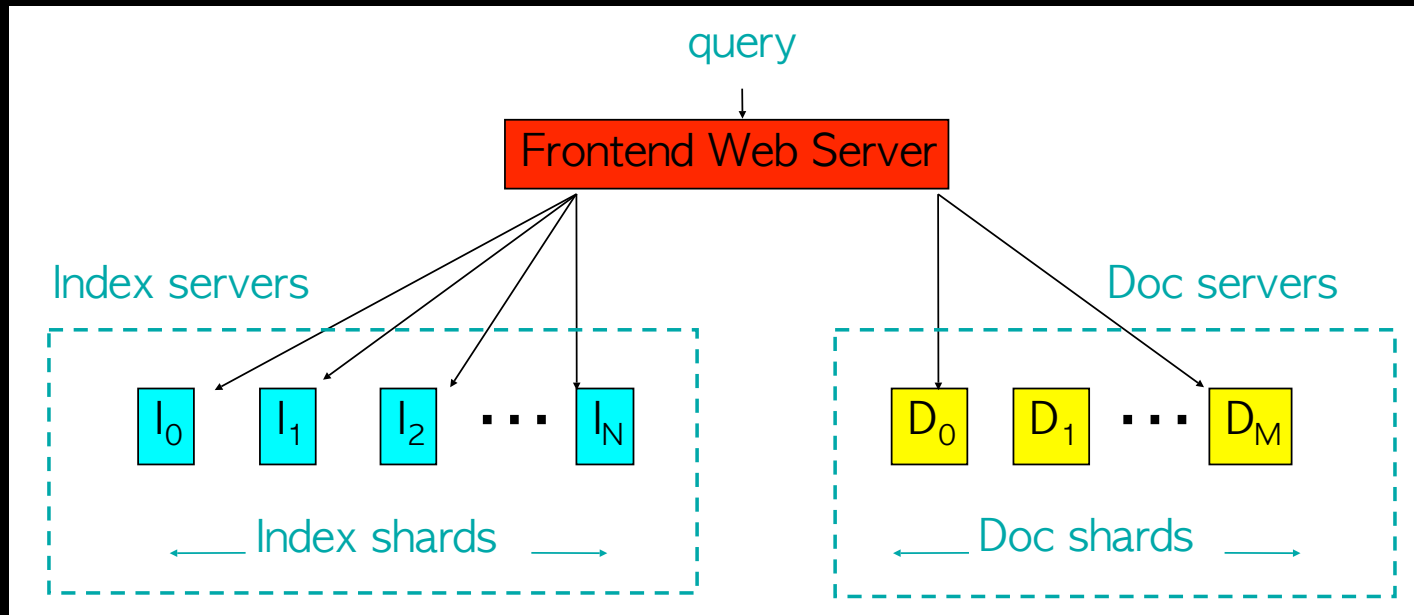


Image from Dean, Google 1997

- Given search terms e.g. dog, cat
- Return pair <docid, score>
- Score is the “secret sauce” for ranking docs
- Doc servers return pre-formatted snippets plus doc address

# Some Questions

- Where are the bottlenecks?
- What is missing?

# Adding Speed and Income

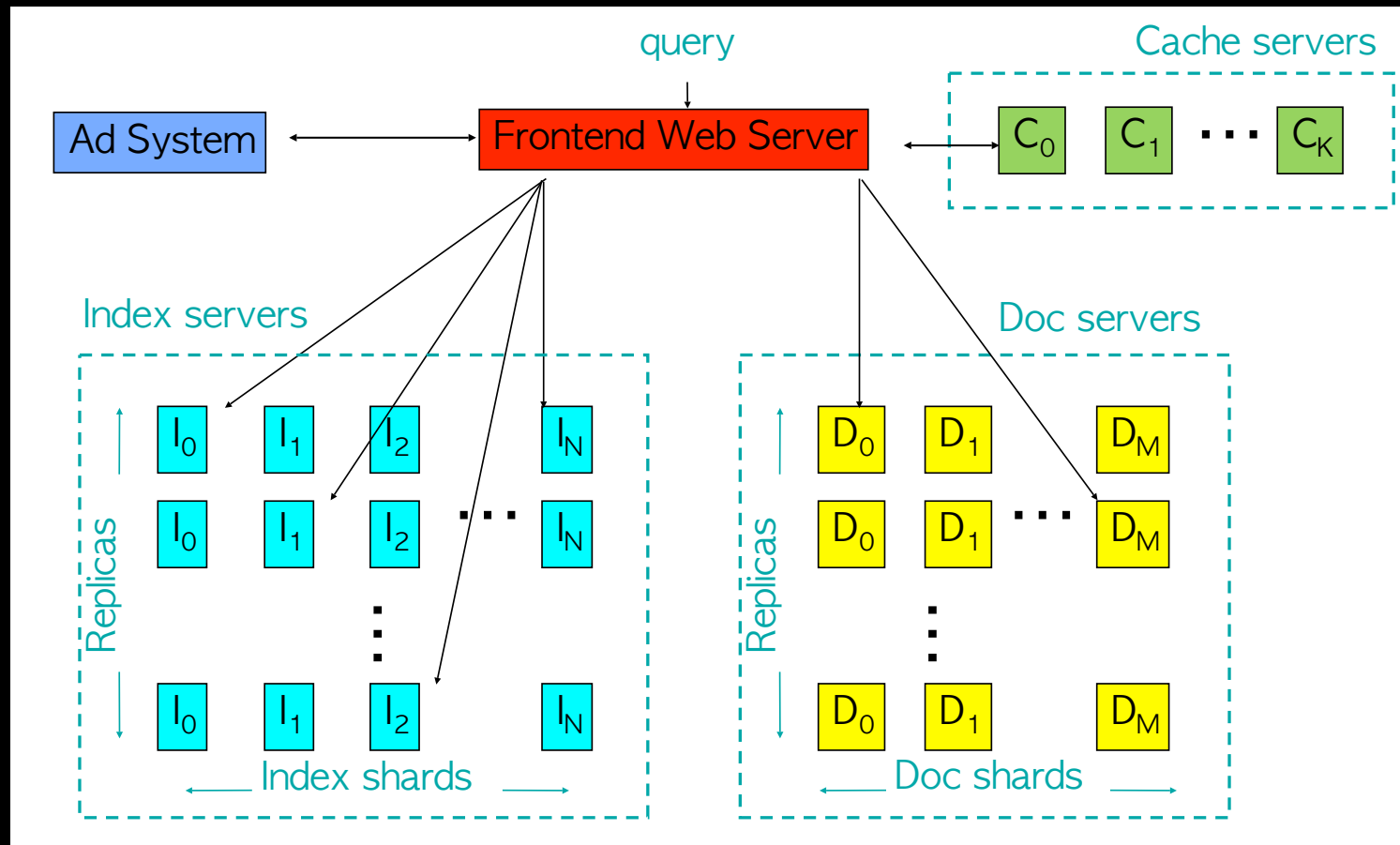
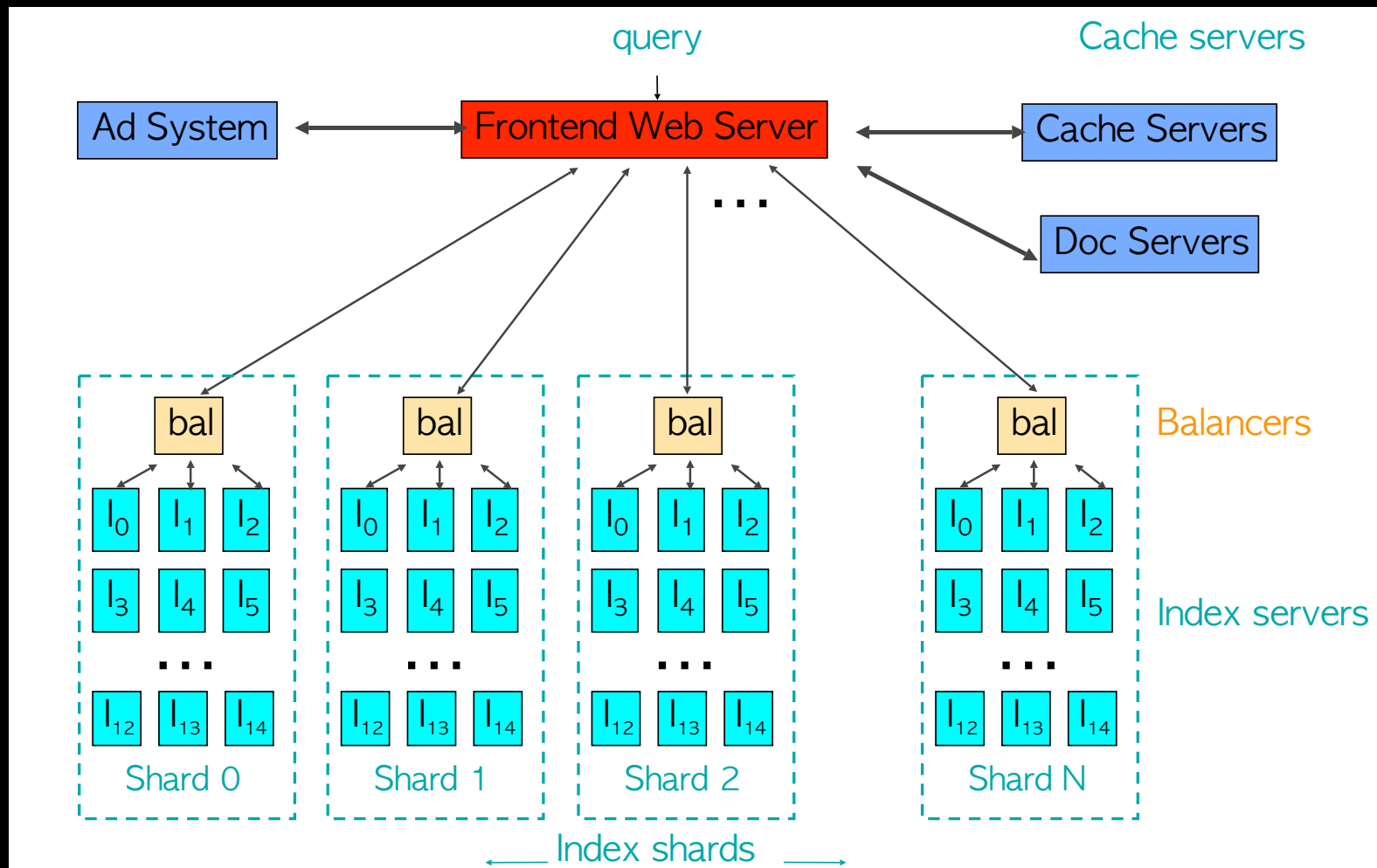


Image from Dean, Google 1999

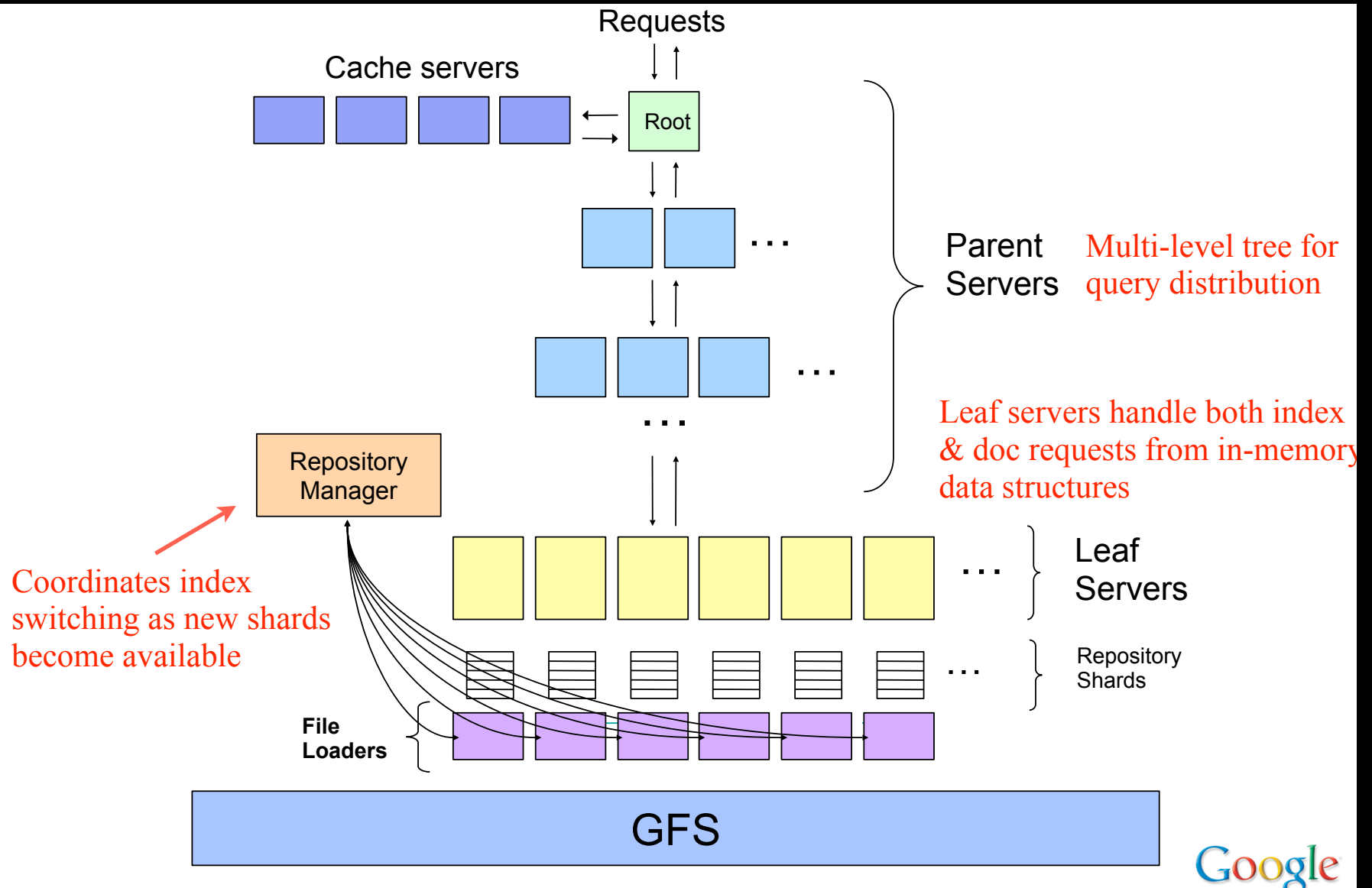
# What Makes an Effective ...

- Search?
- Ad?

# More Scale?



# A More Complete Picture



# Some Interesting Plusses and Minuses

- Queries are now fast – particularly at tail
- Throughput is high
- Now depending on a very large # of machines – one key machine down and that query fails or takes a long time
- What if a query kills a machine – you can mow down the entire cluster

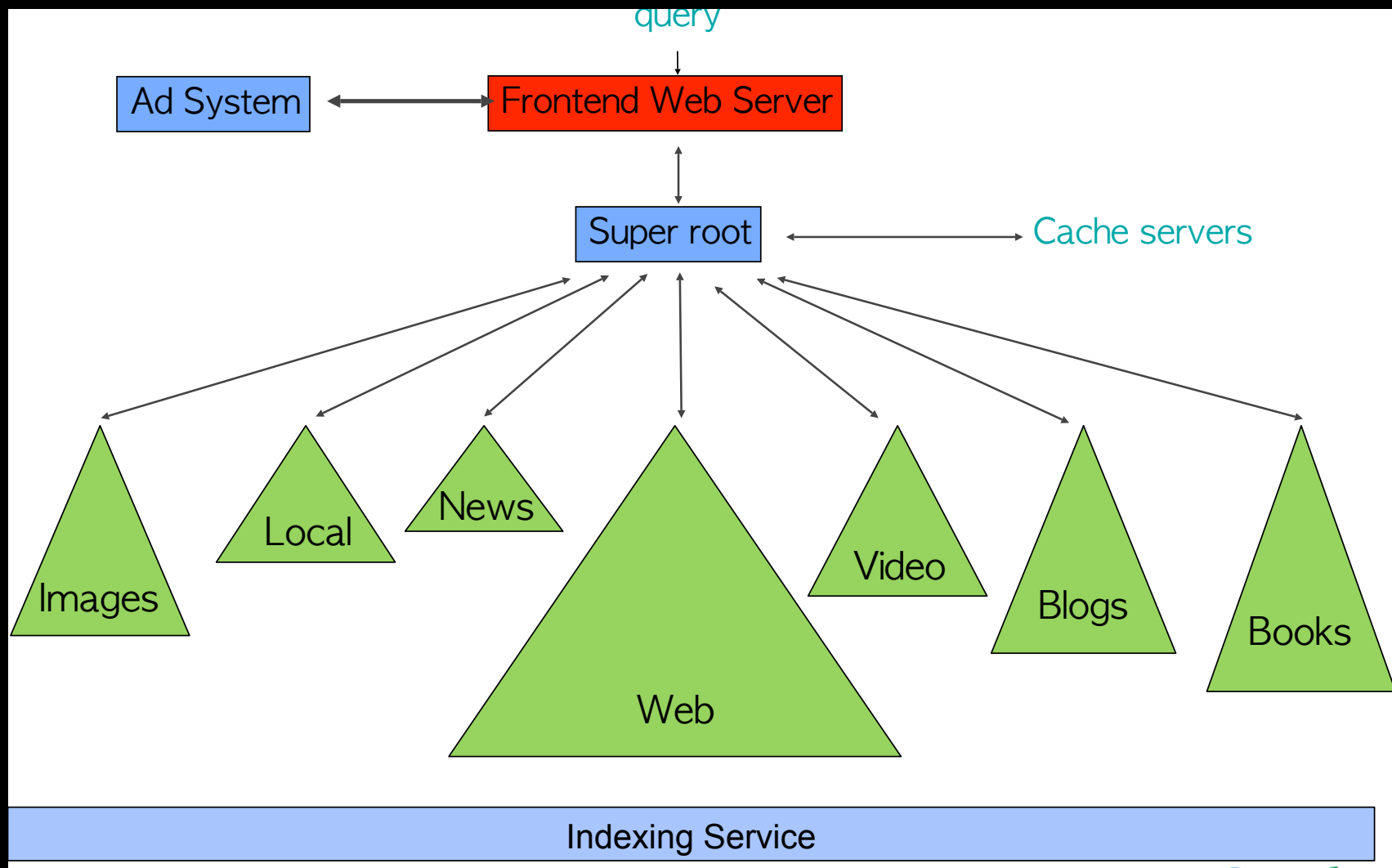


# Canary Requests

- Send a request to one machine and see if it dies
- If not, go ahead
- If it does, try a couple more; if they die, give up



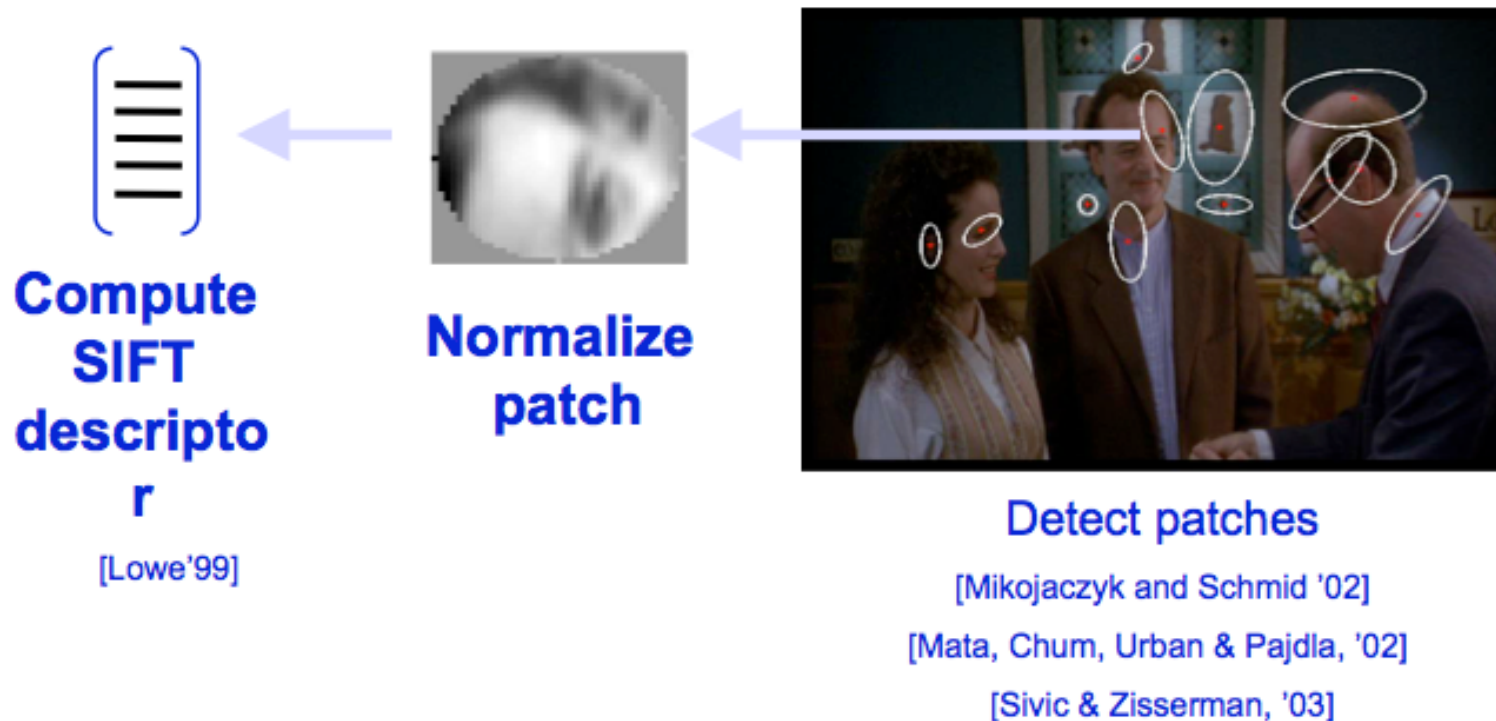
# Google 2007 Architecture



# An Aside – Visual Search

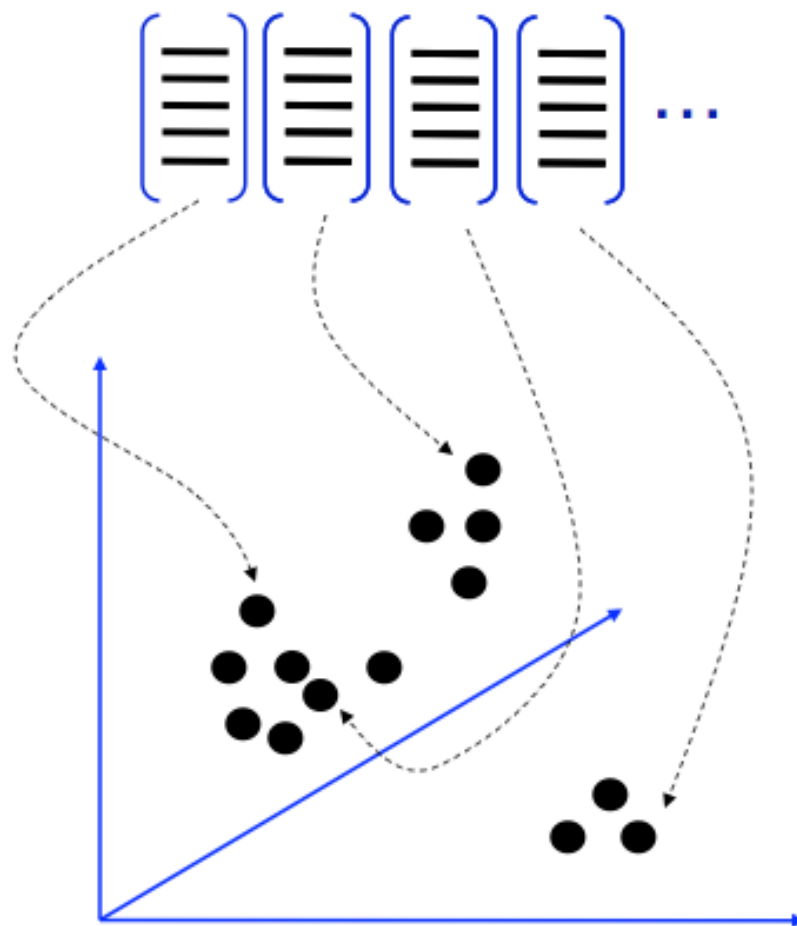
- Key breakthrough due to Lowe (SIFT, 1999)
- Second key technology: use of weak labels from the Web
- Third key technology: learning technologies that can be applied at scale

# 1. Feature detection and representation

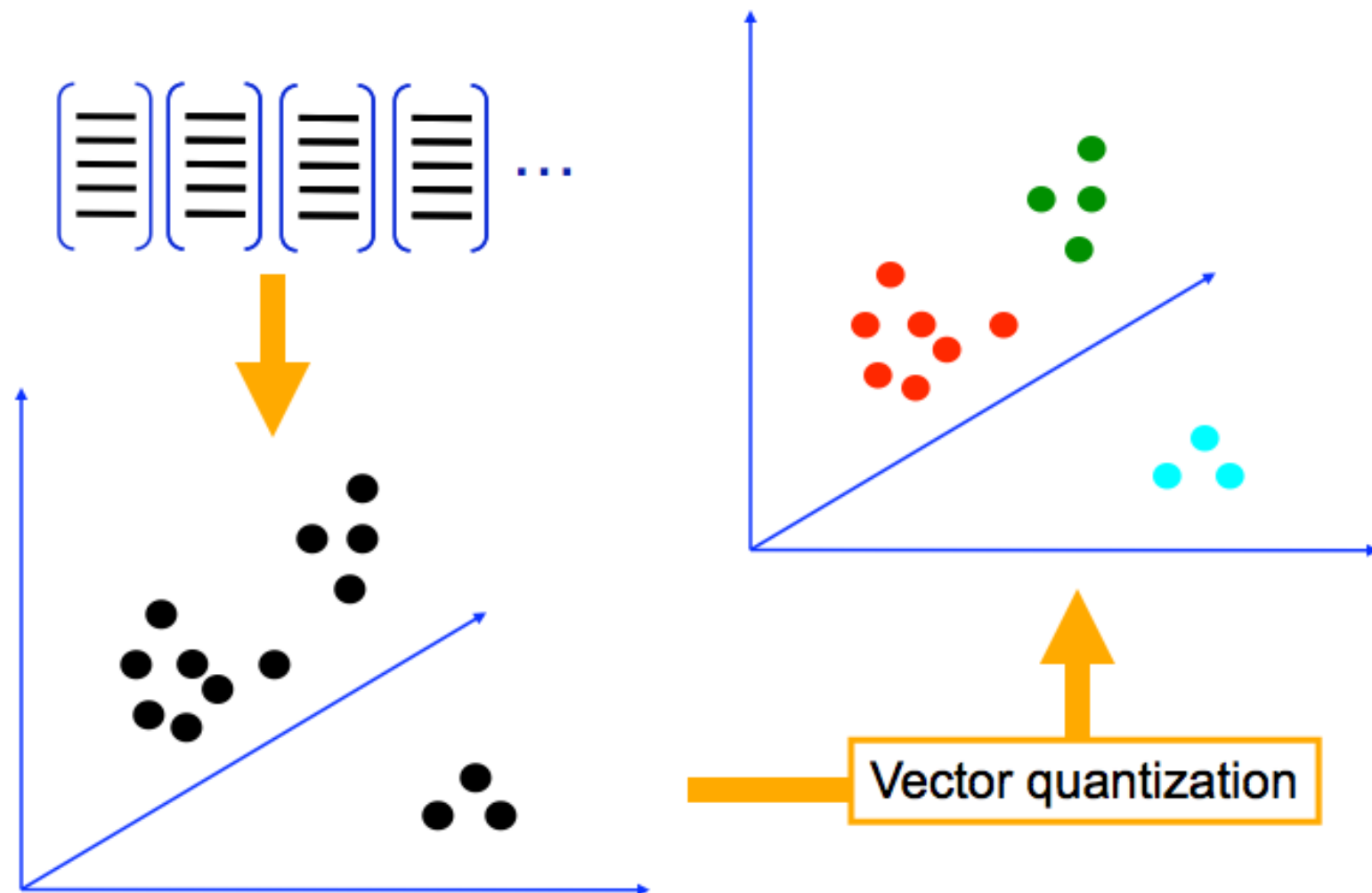


Slide credit: Josef Sivic

## 2. Codewords dictionary formation



## 2. Codewords dictionary formation



Slide credit: Josef Sivic

# Visual Words

- Example: each group of patches belongs to the same visual word

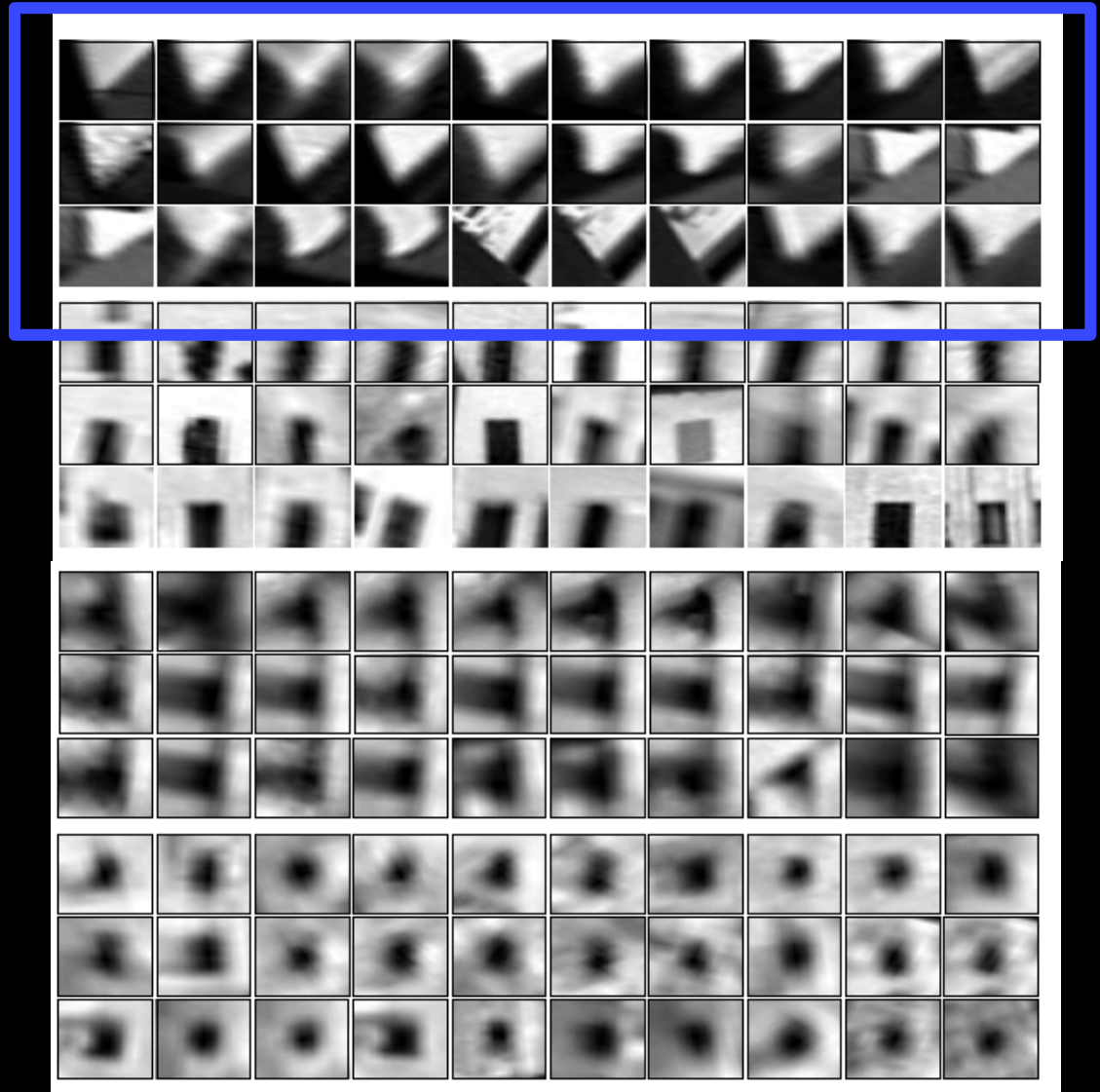
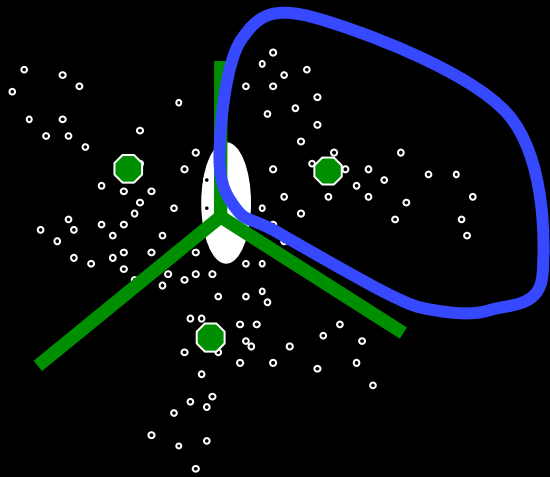


Figure from Sivic & Zisserman, ICCV 2003

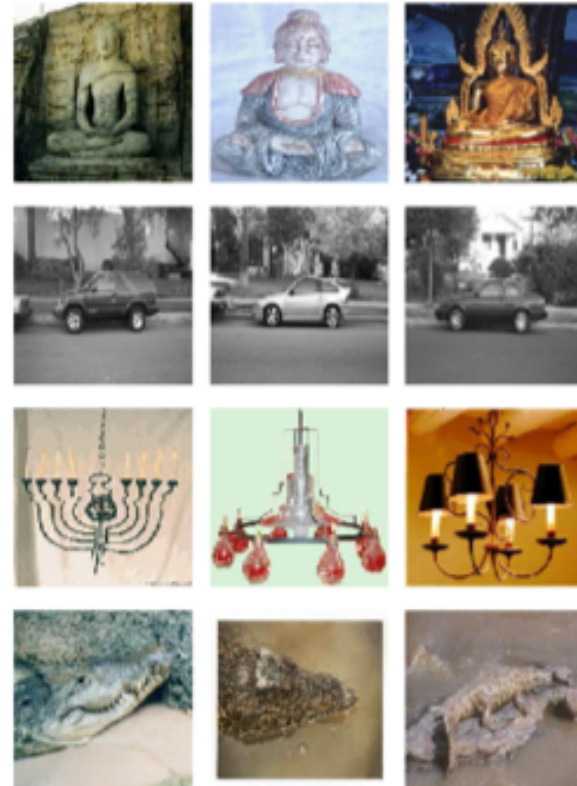
### 3. Image representation





## Object recognition results

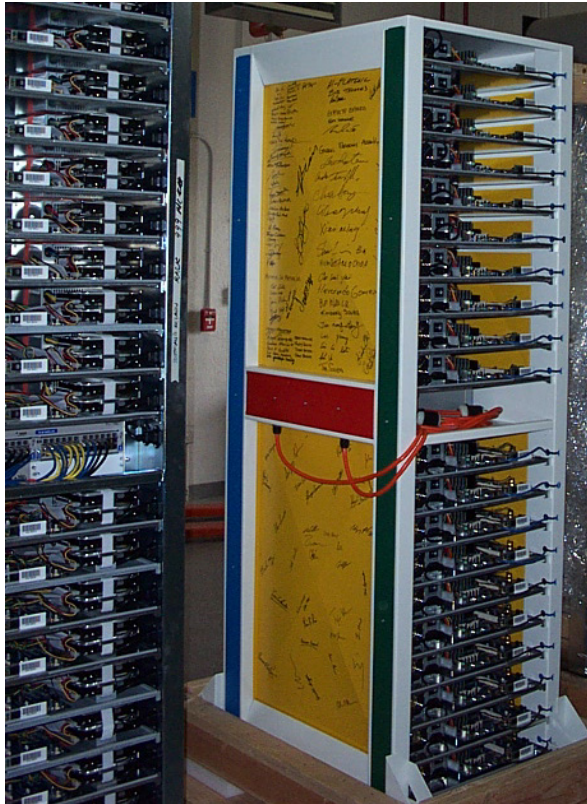
- Caltech objects database  
101 object classes
- Features:
  - SIFT detector
  - PCA-SIFT descriptor,  $d=10$
- 30 training images / class
- **43% recognition rate**  
(1% chance performance)
- 0.002 seconds per match



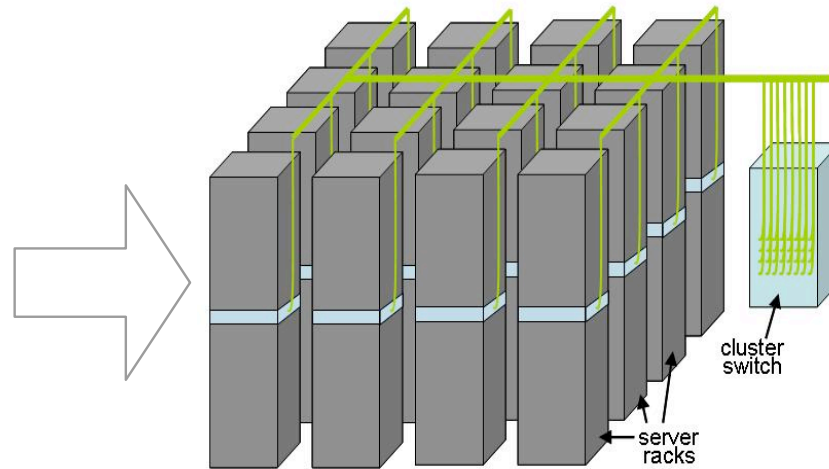
Slide credit: Kristen Grauman

# Running in The Real World

## Machines + Racks



## Clusters



- In-house rack design
- PC-class motherboards
- Low-end storage & networking hardware
- Linux
- + in-house software

# Running in the Real World

Typical first year for a new cluster:

- ~1 **network rewiring** (rolling ~5% of machines down over 2-day span)
- ~20 **rack failures** (40-80 machines instantly disappear, 1-6 hours to get back)
- ~5 **racks go wonky** (40-80 machines see 50% packetloss)
- ~8 **network maintenances** (4 might cause ~30-minute random connectivity losses)
- ~12 **router reloads** (takes out DNS and external vips for a couple minutes)
- ~3 **router failures** (have to immediately pull traffic for an hour)
- ~dozens of minor **30-second blips for dns**
- ~1000 **individual machine failures**
- ~thousands of **hard drive failures**
- slow disks, bad memory, misconfigured machines, flaky machines, etc.**

# Time for a Reality Check

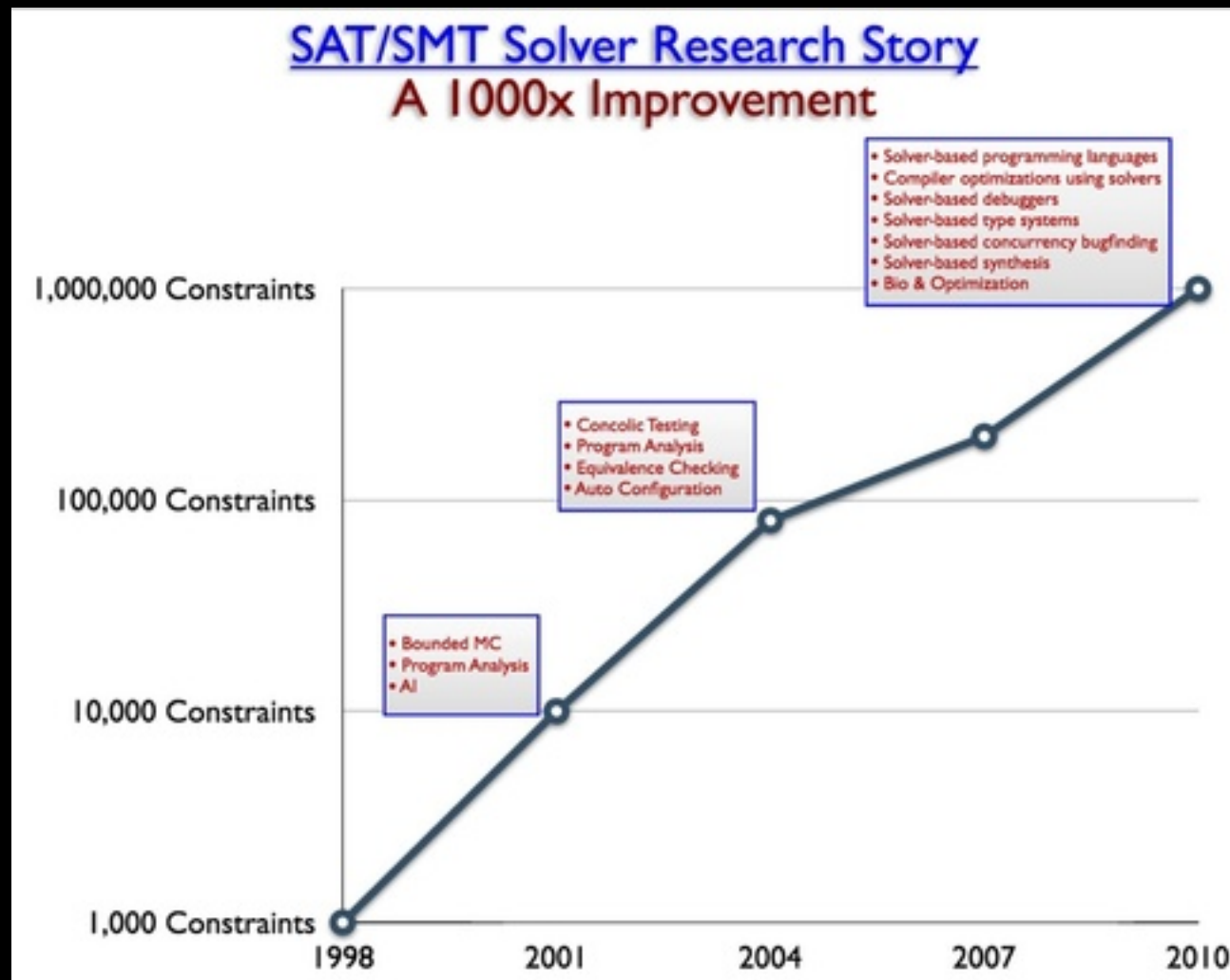
- Suppose you have a bug that is exercised once in a million queries
- How often will that bug be exercised in a day at Google?

3.5 billion queries/day -> 40k/second -> **every 25 seconds,**

# A Slight Digression – SAT and Program Verification

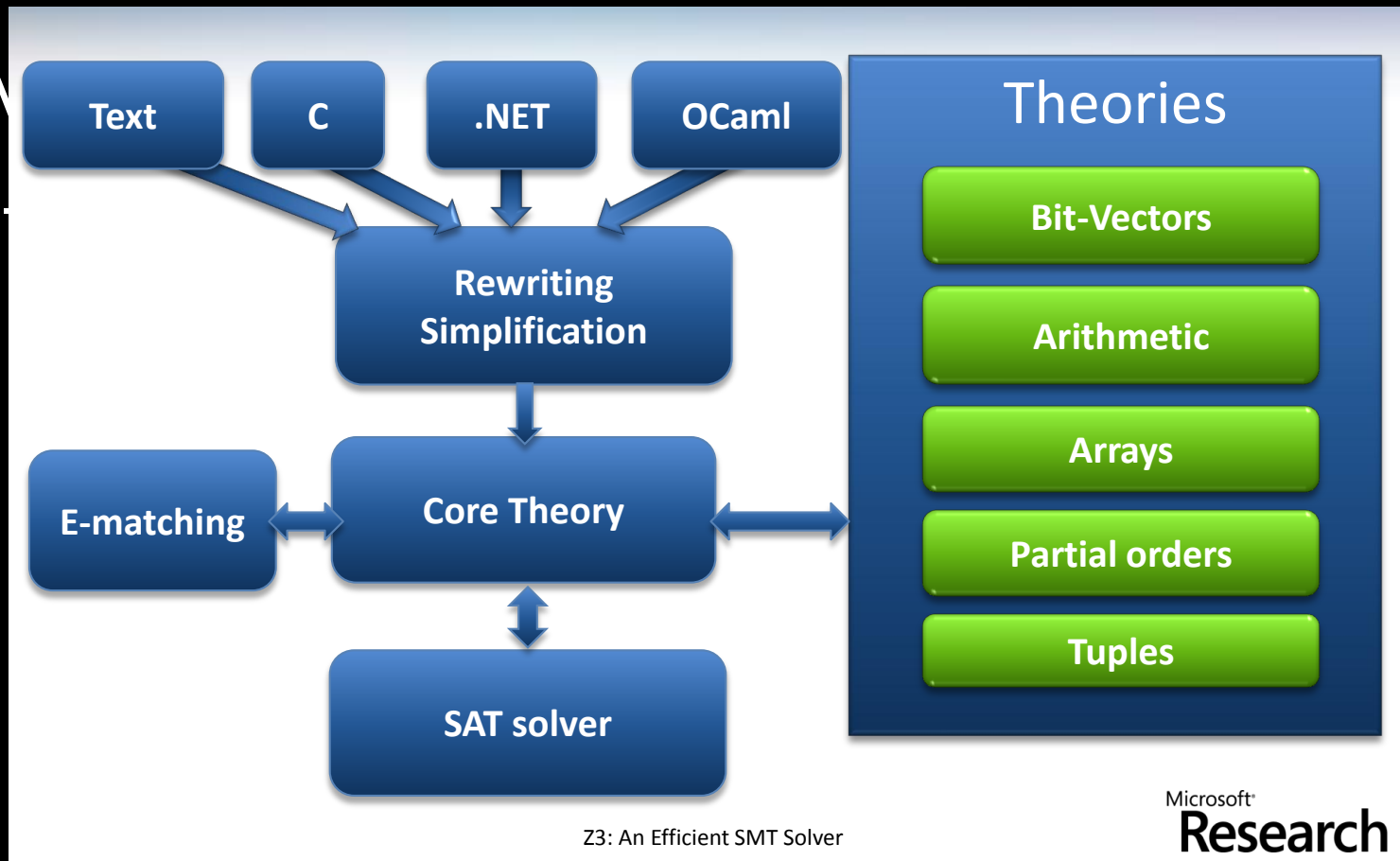
- Simple problem: is a boolean formula satisfiable?
  - $A \ \& \ B \implies \text{yes } A=1, B=1$
  - $A \ \& \ \sim A \implies \text{no!}$
- Original NP complete problem (Cook 1971)
- So What?

# A Slight Digression -- SAT



# Add Some Horsepower

- 



**A large fraction of windows bugs now found by program verifications**

[http://research.microsoft.com/en-us/um/redmond/projects/z3/Z3\\_System.pdf](http://research.microsoft.com/en-us/um/redmond/projects/z3/Z3_System.pdf)

# Time for a Reality Check

- Suppose you have a bug that is exercised once in a million queries
- How often will that bug be exercised in a day at Google?

3.5 billion queries/day -> 40k/second -> **every 25 seconds,**

- Even more complicated because queries are highly parallel!



# A Paradigm Is Born

- Every problem has to deal with all of the possible hardware and software exceptions – lots of work!
- BUT, many of the underlying computations are “embarrassingly parallel”
  - Send a query to server (e.g. “do you have this term”)
  - Aggregate the results
- The idea of **Map-Reduce**

# Map Reduce

- User writes two main functions
  - Map -> the work each worker has to do – e.g. find docs for an index term
  - Reduce -> the work to combine the results – e.g. find the top n queries based on ranking
- System handles
  - Distribution, load balancing, communication, checkpointing ...
- Apache Hadoop a common (open source) system for Map-Reduce



# Computing at Scale

	Aug, '04	Mar, '06	Sep, '07	May, '10
Number of jobs	29K	171K	2,217K	4,474K
Average completion time (secs)	634	874	395	748
Machine years used	217	2,002	11,081	39,121
Input data read (TB)	3,288	52,254	403,152	946,460
Intermediate data (TB)	758	6,743	34,774	132,960
Output data written (TB)	193	2,970	14,018	45,720
Average worker machines	157	268	394	368

Dean: Map Reduce Statistics

# Some Lessons

- Reality is a harsh taskmaster – many of the best ideas are forged from real problems
- It's usually not a single idea – borrow from the best!
- It's hard to trace the impact of ideas to fruition – at best we can do an anecdotal approximation; don't be fooled by an overly simplistic view!
- There are few truly failed ideas, just failed applications thereof – persevere!

DEPARTMENT OF  
COMPUTER SCIENCE

THE NEW AGE OF DISCOVERY

# Where is Computing Going?

Gregory D. Hager  
Professor and Chair

JOHNS HOPKINS  
UNIVERSITY  
WHITING SCHOOL OF ENGINEERING

# What Do Computers Do Well

- Office work: accounting, wordprocessing
- Simulation: science, gaming
- Automation: manufacturing, embedded systems



# What's Hard?



11/11/14



# Driving





# Automated Driving 1986

## Navlab 1 (CMU)

- 5 racks of computing equipment
- Warp supercomputer
- Vision, laser scanner

By late 80's software systems could drive at 20 m.p.h.

*1986: Dickmanns demonstrates 60 mph driving using simple vision-based control approach*



Fig. 1. The Navlab.

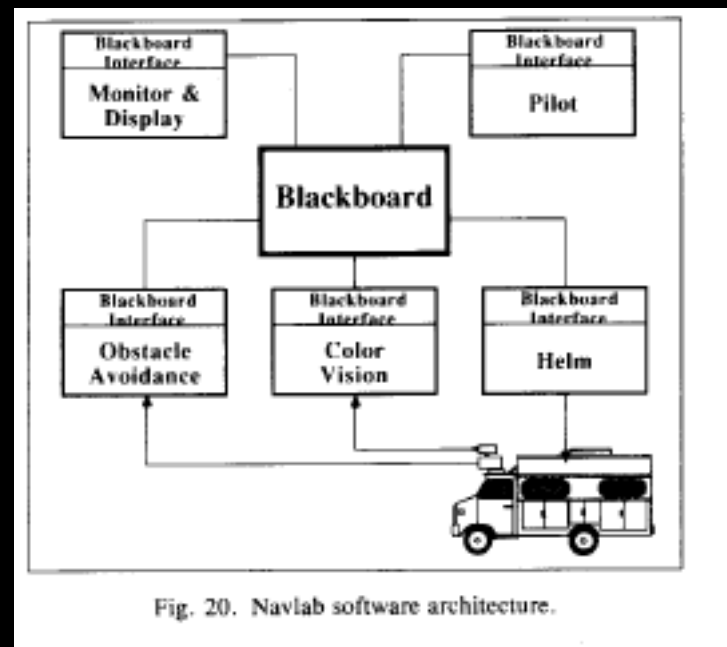


Fig. 20. Navlab software architecture.

# Automated Driving 1996

## Navlab 5: 1990 Pontiac Trans Sport

- Portable Advanced Navigation Support
- Sparc LX with a color video digitizer
- Differential GPS, fiber optic rate gyro
- Position estimation, vehicle control, and safety monitoring.
- Powered from cigarette lighter

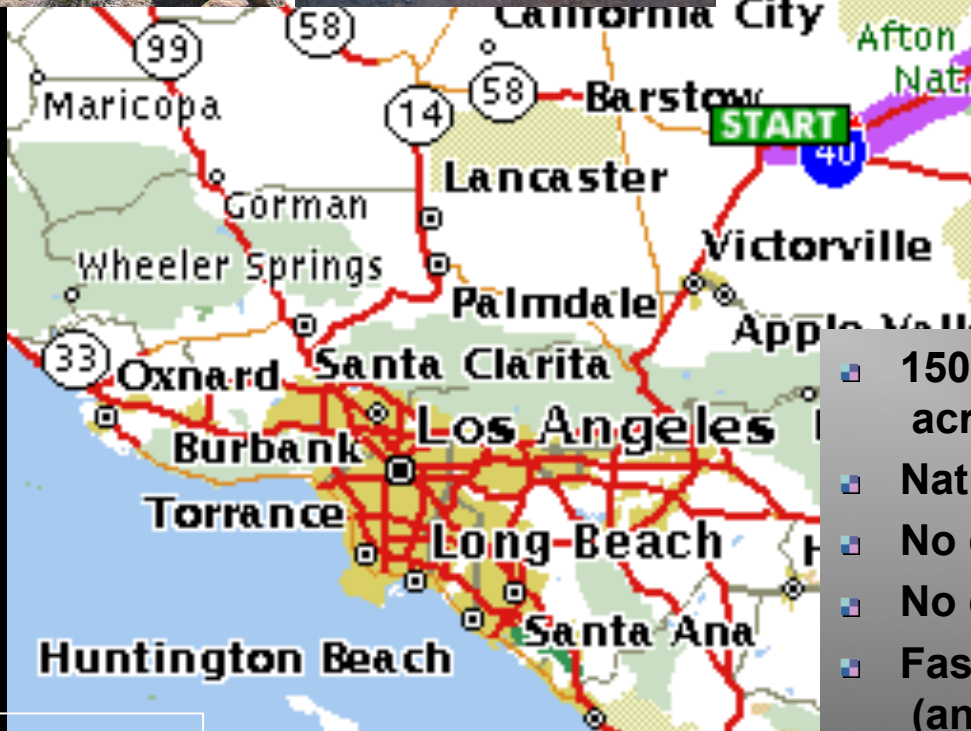


(Pomerleau et al. CMU)

*No Hands Across America*

2797/2849 miles (98.2%)  
*automated driving*

# 2004 DARPA Grand Challenge:



- 150 mile off-road robot race across the Mojave desert
- Natural and manmade hazards
- No driver, no remote control
- No dynamic passing
- Fastest vehicle wins the race (and 2 million dollar prize)

Courtesy Thrun



# July 15: Driving the DGC 2004 Course

Straight Roads



Mountain Roads



Cattle Guards



Open Lake



Stanford Racing Team



# The 2004 DARPA Grand Challenge

- 150 mile course through Mojave Desert
- 15 entrants who made it to the final  
<https://www.youtube.com/watch?v=FaBJ5sPPmcl>
- After a few hours, all failed
- Sandstorm (CMU) made it 7.4 miles

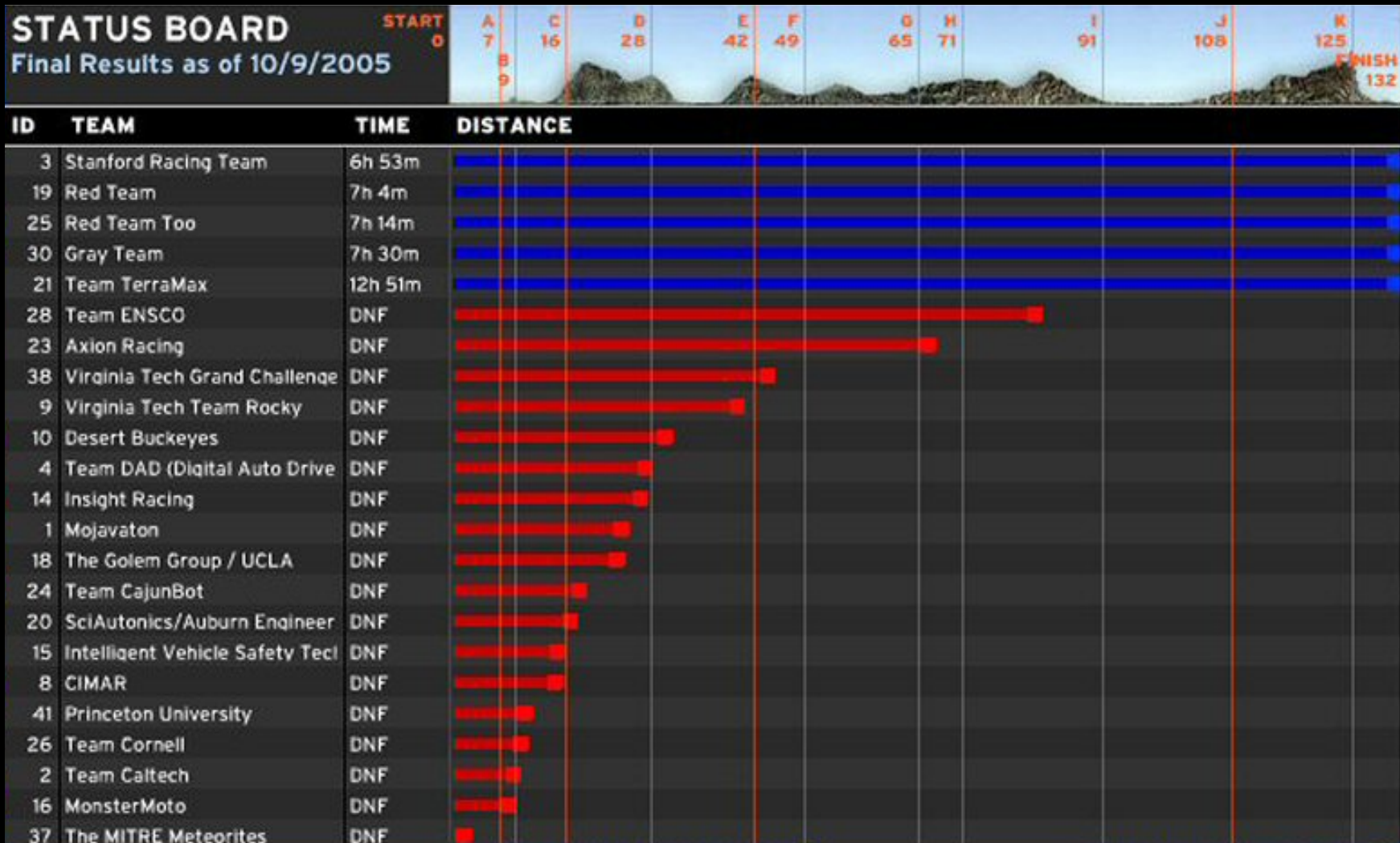




# Grand Challenge 2005: 195 Teams



# Final Result: Five Robots finished!



Stanford Racing Team





# The Winners

- Stanley (Stanford)  
6:54
- Sandstorm (CMU)  
7:05
- Highlander (CMU)  
7:14



11/11/14

Stanford Racing Team





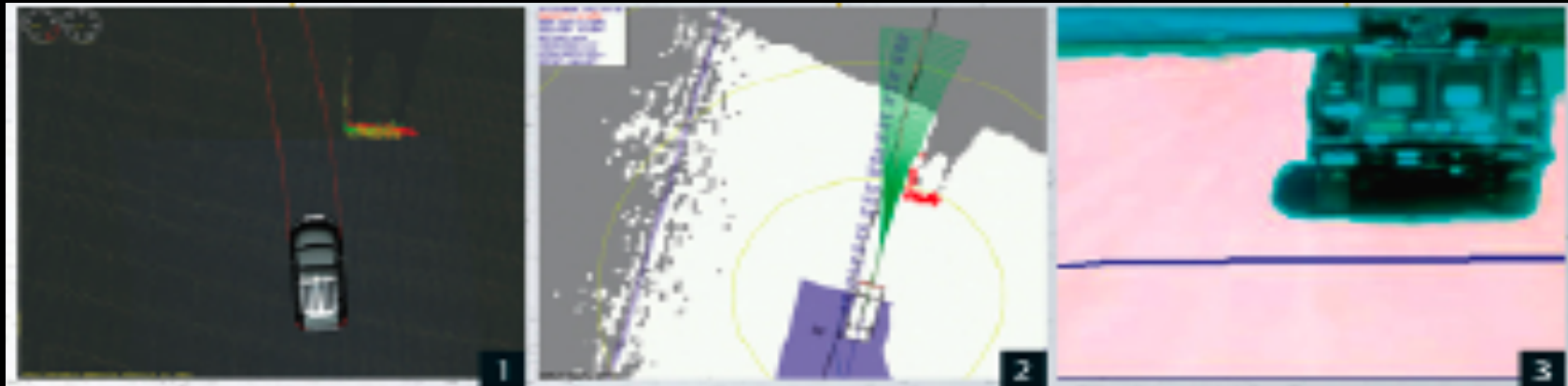
# The Grand Challenge Race



Stanford Racing Team



# Automated Driving 2006



Here, Stanford's self-driving vehicle prepares to pass a robotic Hummer, represented by red and green lines on a 3D terrain map plotted by a light detection and ranging system (1). The Mapper program interprets the map as a grid (2): White cells mean driveable road; red cells, an obstacle; and gray cells, unknown conditions. The Planner then plots safe route options, marked by green lines, around the obstacle. A video camera (3) samples Mapper-defined "good" road (below blue line) and searches for similar-looking terrain ahead.

## GPS Navigation

Three GPS receivers provide data on position, pitch and heading.

## Inertial Guidance

Three gyroscopes and three accelerometers mounted above the rear axle provide detailed orientation data in "6D."

## Light Detection and Ranging

Five LIDAR units at various angles bounce laser beams off rotating mirrors to create a 3D map of terrain up to about 100 ft. away.

## Color Video

A video camera scouts driveable road up to 160 ft. ahead, identifies distant obstacles.

*Stanford  
DARPA  
Grand  
Challenge  
Vehicle  
(Thrun)*

*(Popular Mechanics  
Jan '06)*

# Stanley Software Architecture

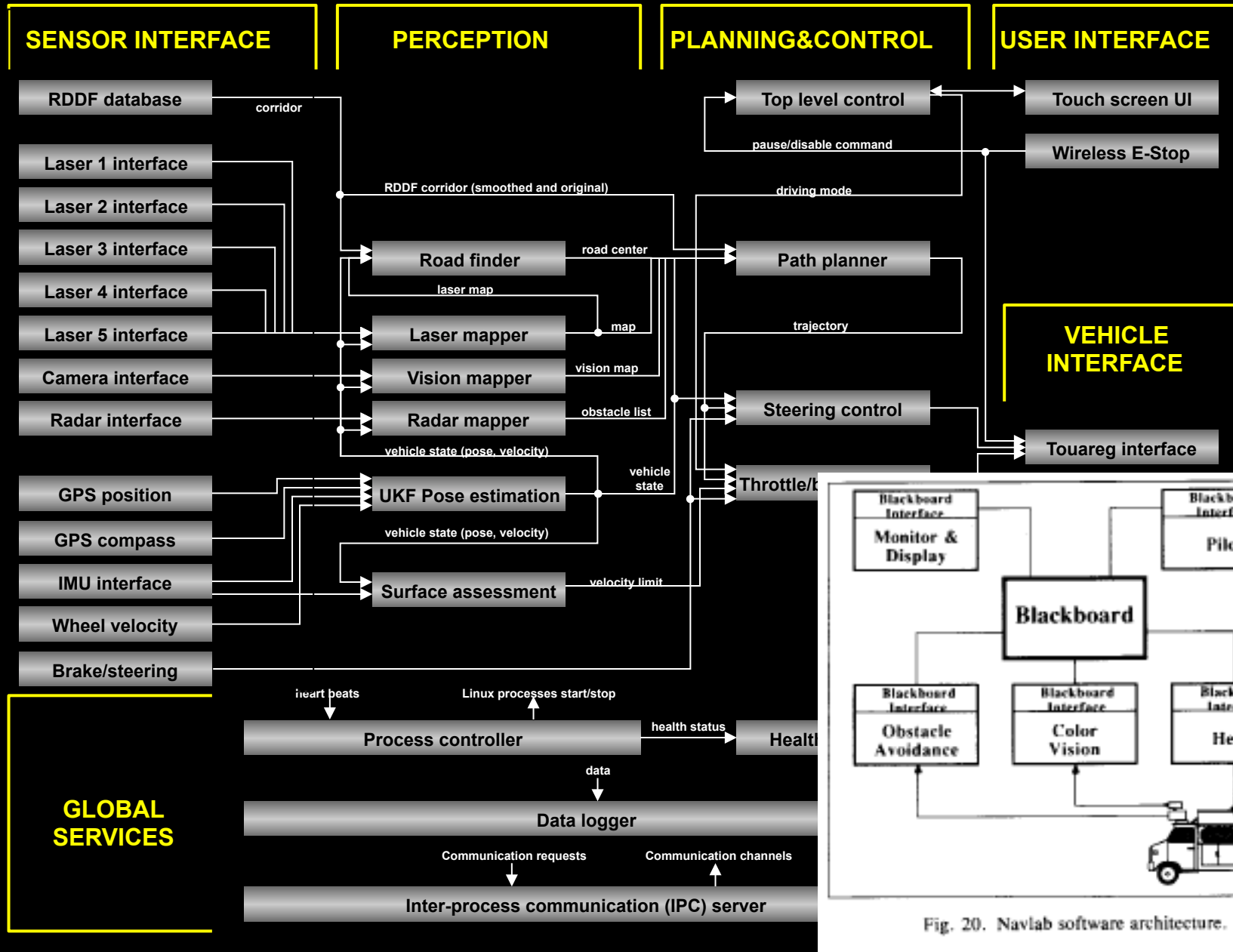
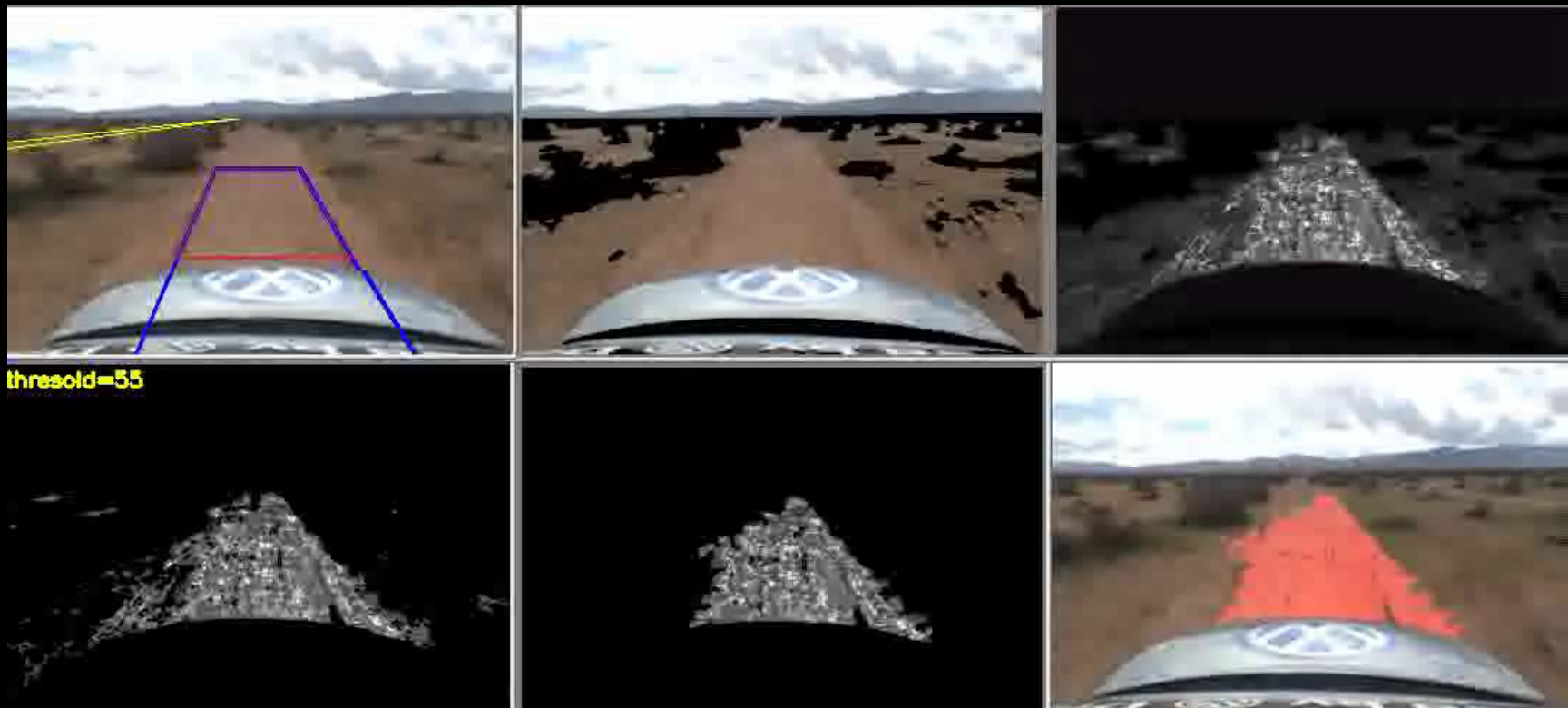


Fig. 20. Navlab software architecture.

# A Look Under the Hood



Courtesy David Stavens, Sebastian Thrun



# Adaptive Vision in Mojave Desert



Stanford Racing Team



# The Next Challenges

- Darpa Urban Challenge: <https://www.youtube.com/watch?v=0wJAANgG-Vg>
- Google Car: <https://www.youtube.com/watch?v=TsaES--OTzM>

# DARPA Robotics Challenge

- 1. Drive a utility vehicle at the site.
- 2. Travel dismounted across rubble.
- 3. Remove debris blocking an entryway.
- 4. Open a door and enter a building.
- 5. Climb an industrial ladder and traverse an industrial walkway.
- 6. Use a tool to break through a concrete panel.
- 7. Locate and close a valve near a leaking pipe.
- 8. Connect a fire hose to a standpipe and turn on a valve.

# DARPA Robotics Challenge





# What Computers Can't Do (Yet?)

# The Popular View of Computers



# Simon 1957

- Predicted that by 1967:
  - A computer would be world champion in chess
  - A computer would discover and prove an important new mathematical theorem
  - Most theories in psychology will take the form of computer programs.

# And so far ...

- A computer would be world champion in chess
  - On May 11, 1997, the machine won the second six-game match against world champion Garry Kasparov, two to one, with three draws.
- A computer would discover and prove an important new mathematical theorem
  - The four color theorem was proven in 1976 by Kenneth Appel and Wolfgang Haken. It was the first major theorem to be proved using a computer.
- Most theories in psychology will take the form of computer programs.
  - Hmmm, still waiting ...

# Some Seemingly Simple Problems



## Arithmeticon Liber II. 61

intervalum numerorum 2, minor autem 1 N. atque ideo maior 1 N. + 2. Oportet itaque 4 N. + 4, triplos esse ad 2, & adhuc superaddere 10. Ter igitur 2, additis unitatibus 10, aequatur 4 N. + 4. & fit 1 N. 3. Erit ergo minor 3, maior 5, & satisfaciunt quaestioni.

### IN QVAESTIONEM VII.

CONDITIONIS apponitur eadem ratio est quae & apponitur precedenti quaestioni, illi enim casibus requiritur quāvis ut quadratus intervalli numerorum fit minor intervallo quadratorum, & Canones iidem hic etiam locum habebunt, ut manifestum est.

### QVAESTIO VIII.

PROPOSITUM quadratum dividere in duos quadratos. Imperatum fit ut 16. dividatur in duos quadratos. Ponatur primus 1 Q. Oportet igitur 16 - 1 Q. aequales esse quadrato. Fingo quadratum a numeris quotquot libuerit, cum defectu tot unitatum quod continet latus ipsius 16. Effo 22 N. - 4. Ipe igitur quadratus erit 4 Q. + 16. - 16 N. hanc aequabuntur unitatibus 16 - 1 Q. Communis adiciatur utrimque defectus, & a similibus auferantur similia, fient 5 Q. aequales 16 N. & fit 1 N. 5. Erit igitur alter quadratorum 16. alter vero 16 & utriusque summa est 16 seu 16. & uterque quadratus est.

### OBSERVATIO DOMINI PETRI DE FERMAT.

Utrum autem in duos cubos, aut quadratoquadratum in duos quadratoquadratos & generaliter nullum in infinitum plura quadratorum potestatem in duos eiusdem nominis fas est dividere cuius rei demonstrationem mirabilem sane detexi. Hanc marginis exiguitas non caperet.

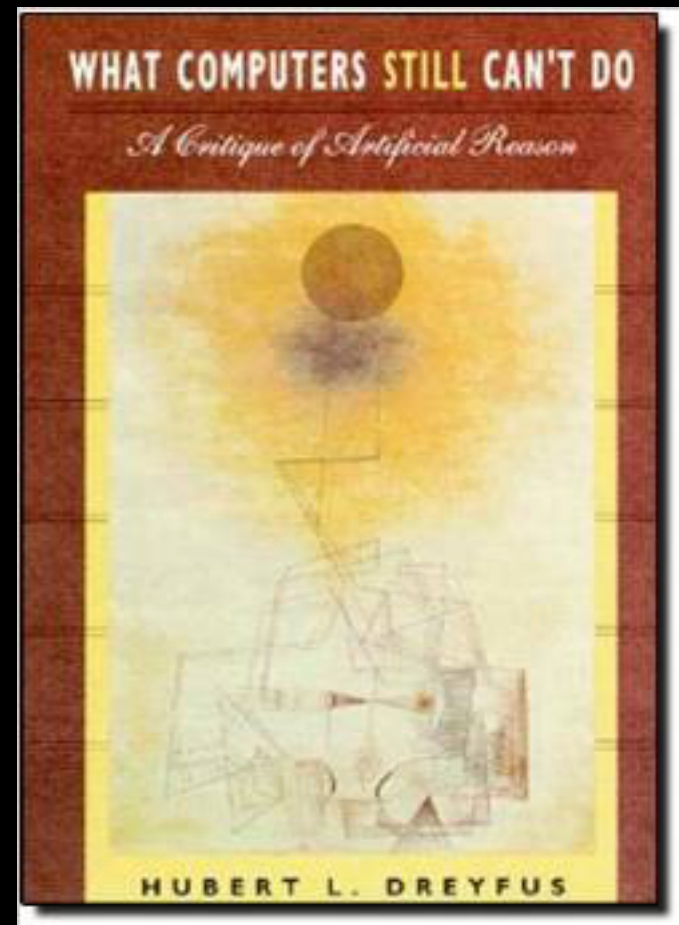
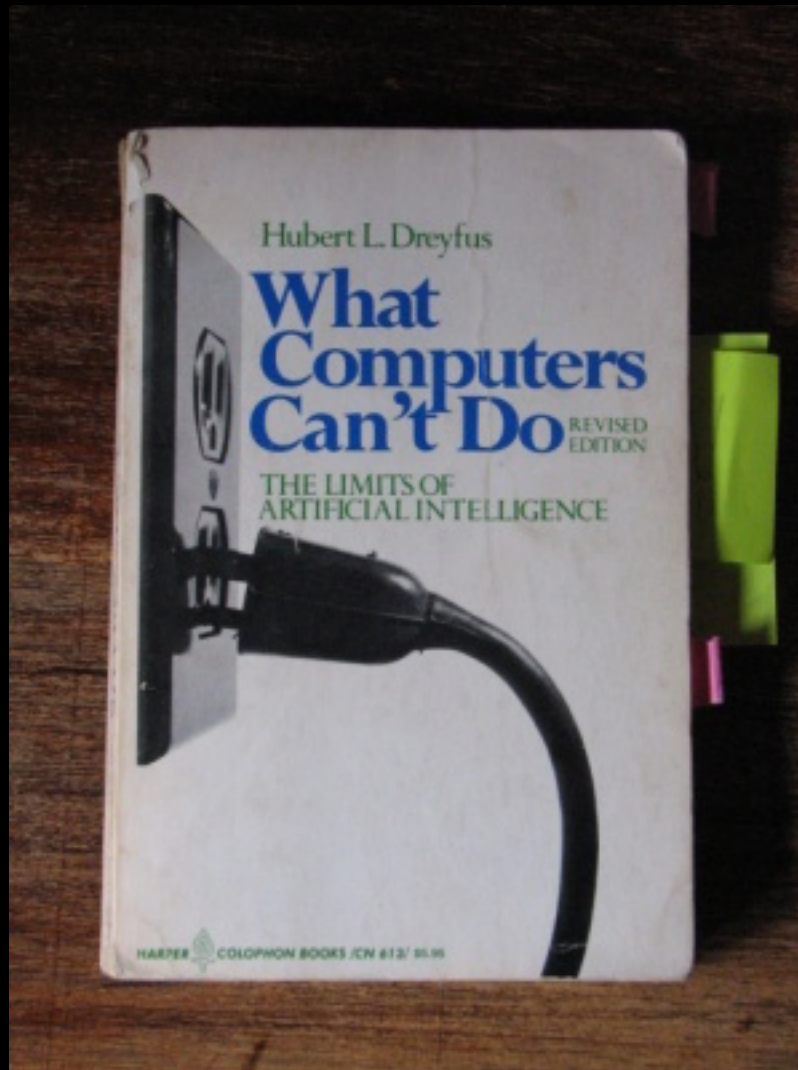
### QVAESTIO IX.

REVERSUS oporteat quadratum 16 dividere in duos quadratos. Ponatur tursus primi latus 1 N. alterius vero quotcumque numerorum cum defectu tot unitatum, quot constet latus diuidendi. Effo itaque 2 N. - 4. erunt quadrati, hic quidem 1 Q. ille vero 4 Q. + 16. - 16 N. Ceterum volo utrumque simul aequari unitatibus 16. Igitur 5 Q. + 16. - 16 N. aequatur unitatibus 16. & fit 1 N. 5. erit



$A^n + B^n = C^n$  for  
Integers A, B, C  
and  $n > 2$ ?

# Dreyfus 1972, 1992



# AI Will Fail Because ....

- **The biological assumption**
  - *The brain processes information in discrete operations by way of some biological equivalent of on/off switches.*
- **The psychological assumption**
  - *The mind can be viewed as a device operating on bits of information according to formal rules.*
- **The epistemological assumption**
  - *All knowledge can be formalized.*
- **The ontological assumption**
  - *The world consists of independent facts that can be represented by independent symbols*

# And Now??

- Can a computer create music?
  - <https://www.youtube.com/watch?v=PzrcoqpnZqA>



# And Now??

- Can a computer create music?
  - <https://www.youtube.com/watch?v=PzrcoqpnZqA>

# Some Questions

- Can a computer create music?
  - <https://www.youtube.com/watch?v=PzrcoqpnZqA>
- Can a computer write an article?

**This is the article generated by the LA Times algorithm:** A shallow magnitude 4.7 earthquake was reported Monday morning five miles from Westwood, California, according to the U.S. Geological Survey. The temblor occurred at 6:25 a.m. Pacific time at a depth of 5.0 miles.

According to the USGS, the epicenter was six miles from Beverly Hills, California, seven miles from Universal City, California, seven miles from Santa Monica, California and 348 miles from Sacramento, California. In the past ten days, there have been no earthquakes magnitude 3.0 and greater centered nearby.

This information comes from the USGS Earthquake Notification Service and this post was created by an algorithm written by the author.

# Some Questions

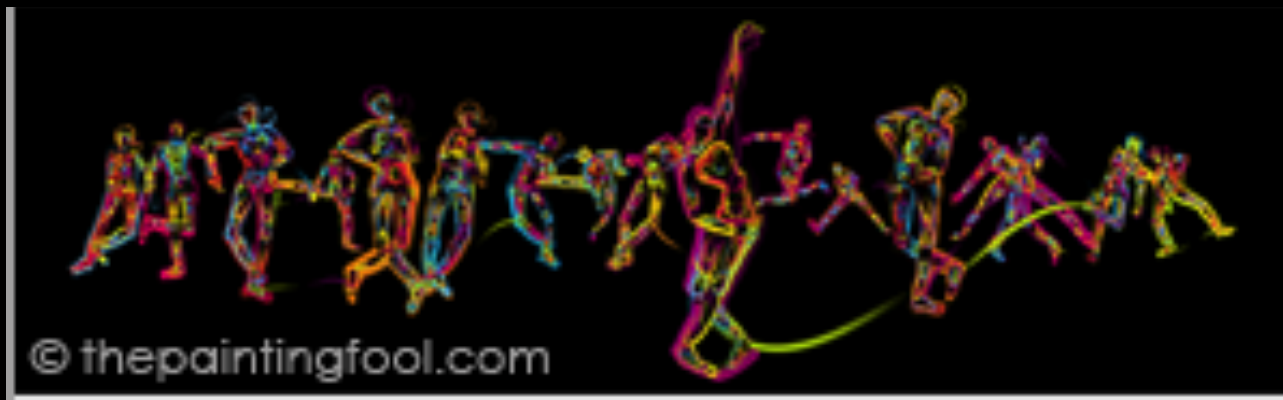
- Can a computer create music?
  - <https://www.youtube.com/watch?v=PzrcoqpnZqA>
- Can a computer write an article?

Friona fell 10-8 to Boys Ranch in five innings on Monday at Friona despite racking up seven hits and eight runs. Friona was led by a flawless day at the dish by Hunter Sundre, who went 2-2 against Boys Ranch pitching. Sundre singled in the third inning and tripled in the fourth inning ... Friona piled up the steals, swiping eight bags in all ...

<http://www.narrativescience.com>

# Some Questions

- Can a computer create music?
  - <https://www.youtube.com/watch?v=PzrcoqpnZqA>
- Can a computer write an article?
- Can a computer paint?

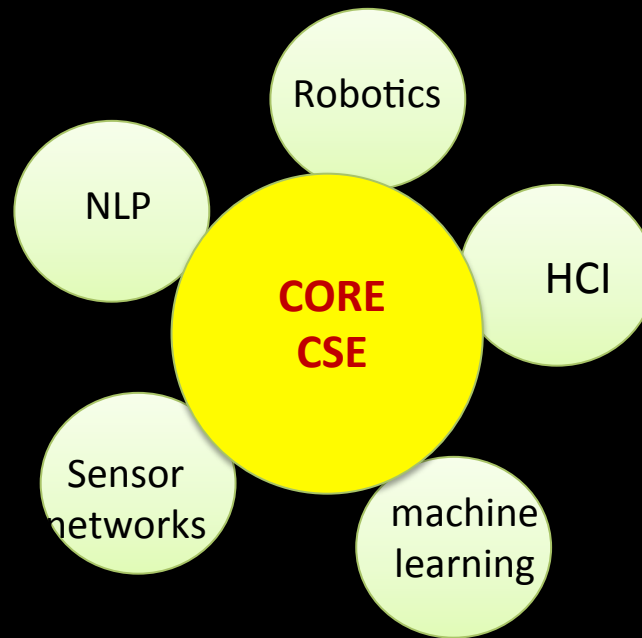


<http://www.thepaintingfool.com>

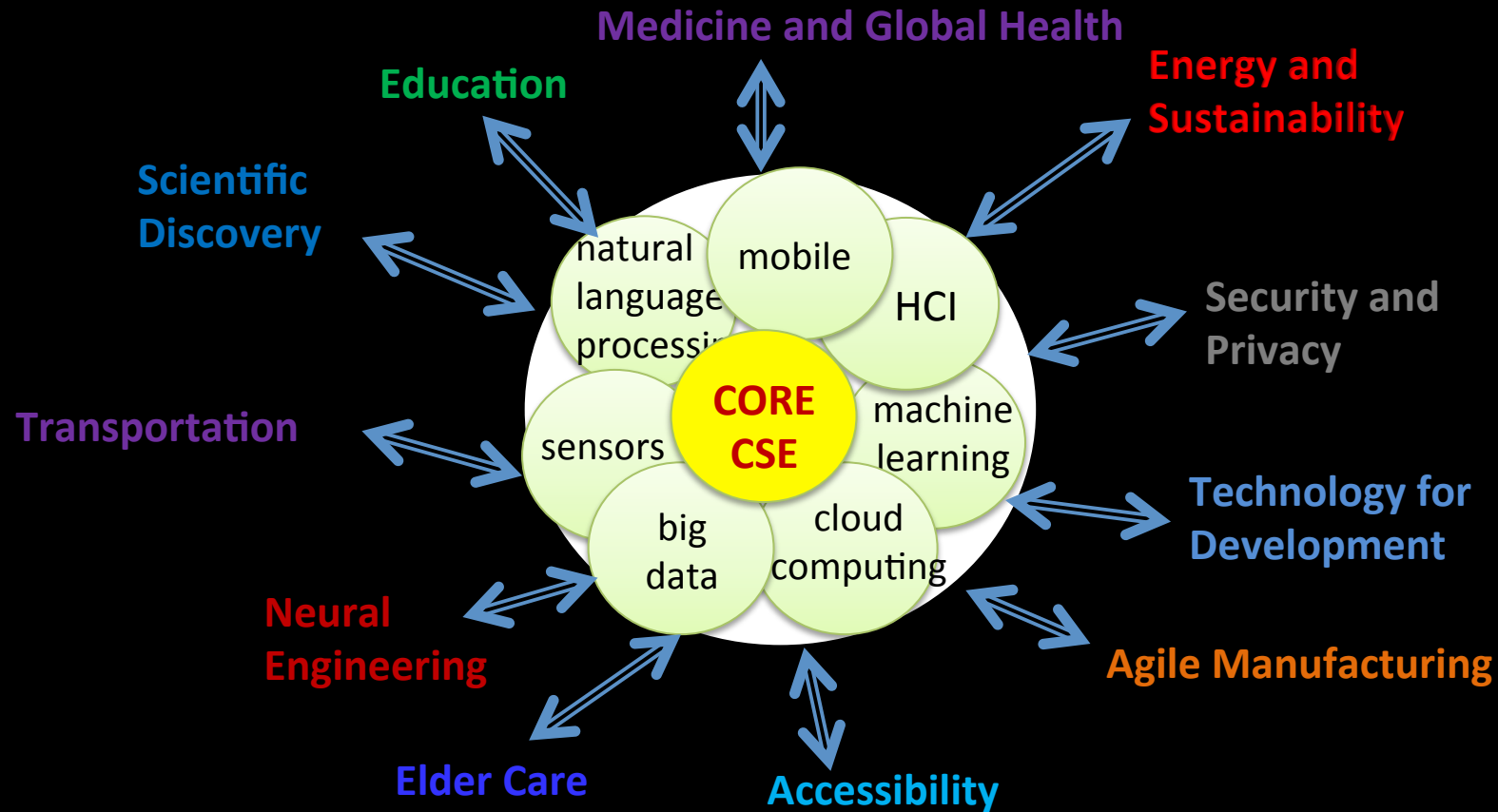
# What Would Intelligence Mean?



# Computing as it is Today



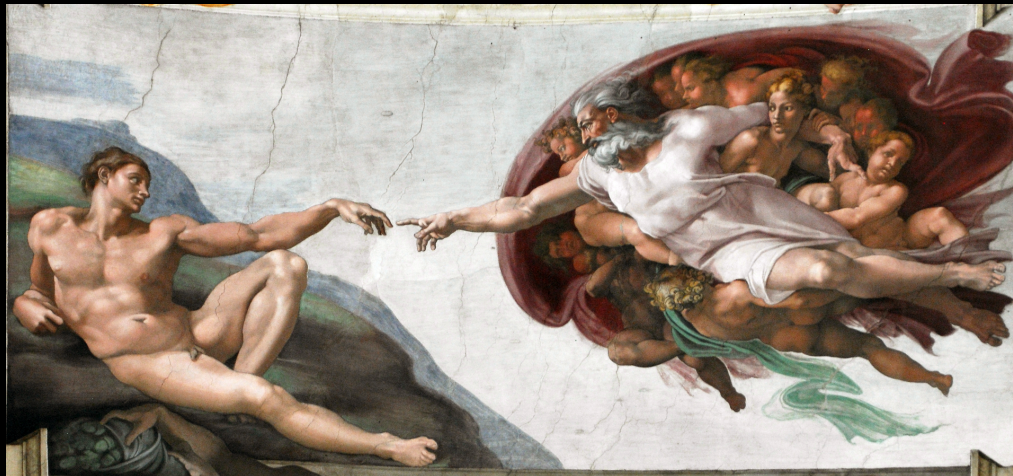
# Where Computing is Going



**Drivers: Industry, Society, Government, Science**

# What Is Our Future? How Will We Shape It?

Is Computing the  
future of thought  
and discourse?



Is Computing creating a new ways to combine  
and create?

USC 2014, GD Hager



Is it the beginning of the  
end of Computing as  
we know it?