

# How to think big

Udi Manber

Google

# Computer Science is changing

- The 20<sup>th</sup> century was about taming nature (and winning wars)
  - dams, roads, airplanes, rockets, ...
- I think the 21<sup>st</sup> century will be about *understanding people*
  - health, communication, education, knowledge, ...
- Computer Science is leading the way, but it's a different computer science

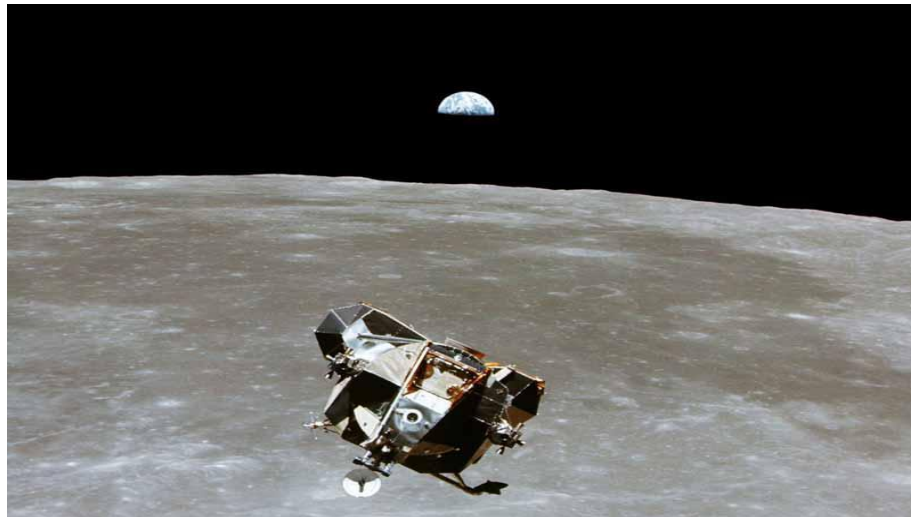
- I started working on search when Gene Myers came to my office one day in 1989 and presented an interesting problem he was working on.
- We went back and forth with ideas, and in 24 hours we got the basic design of Suffix Arrays.
- It was one of the most exciting 24 hours of my life

If I had known in 1989 everything I know today about search, it wouldn't have helped much – there was very little that I could have done with that knowledge

# Technology revolution since 1982

- CPU performance has gone up by a factor of **3500** (1 MHz – 3.5GHz)\*
- Memory prices per megabyte are down by a factor of **45,000** (\$3,500 to 7.8 cents)\*
- Disk prices per megabyte are down by a factor of **3,600,000** (\$1,200 to .033 cents)\*

# If only gas mileage improved as much as disk prices



- One gallon of gas would take you to the moon and back 114 times!
- (costing \$1.30)



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gas prices in 1982

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## Web

News results for **gas prices in 1982** - [View today's top stories](#)



Bush moves to quell anger over **gas price** - [Globe and Mail](#) - Apr 26, 2006

### [Gasoline Price History](#)

Gasoline **Price** History. The following plot shows how much I paid for each gallon of **gas** I bought over the past 26 years or so. ...

[www.randomuseless.info/gasprice/gasprice.html](http://www.randomuseless.info/gasprice/gasprice.html) - 3k -

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### [1980s Flashback-Economy / Prices](#) - Apr 26

1982 Economy / **Prices**. Cost of a gallon of regular **gas**:, \$1.30. Cost of a dozen eggs:, \$0.84. Cost of a gallon of Milk:, \$2.24 ...

[www.1980sflashback.com/1982/Economy.asp](http://www.1980sflashback.com/1982/Economy.asp) - 21k - [Cached](#) - [Similar pages](#) - [Remove result](#)

### [AAA Michigan - Fuel Gauge Report](#)

1982, \$1.309. 1983, \$1.264. 1984, \$1.251. 1985, \$1.236. 1986, \$0.940 ... **Gas prices** jumped 32 cents per gallon; from \$1.042 (in Detroit area) in July 1990 ...

[www.autoclubgroup.com/michigan/autos/fuel\\_gauge.asp](http://www.autoclubgroup.com/michigan/autos/fuel_gauge.asp) - 28k -

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### [Bruce Bartlett Opinion Editorial: Gasoline Rises to its 1982 Price](#)

Gasoline Rises To Its 1982 **Price**. Drivers understandably are upset over the ... It was the Carter Administration's blundering that gave us long **gas** lines in ...

[www.ncpa.org/oped/bartlett/mar1300.html](http://www.ncpa.org/oped/bartlett/mar1300.html) - 6k - [Cached](#) - [Similar pages](#) - [Remove result](#)

### [The Foundation For Taxpayer & Consumer Rights \(FTCR\)](#)

The memo's date, 1982, is particularly significant because that is when federal ... "Divorcement" would prohibit refiners from setting retail **gas prices**, ...

[www.consumerwatchdog.org/co/?postId=4211&](http://www.consumerwatchdog.org/co/?postId=4211&pageTitle=The+High+Price+of+Gasoline+Is+All+About+Power)

[pageTitle=The+High+Price+of+Gasoline+Is+All+About+Power](#) - 18k -

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### [History and Analysis -Crude Oil Prices](#)

## Google Data Center (circa 2000)



A Google data center (circa 2006)



# The web changed everything

- By the middle of 1993, right after Mosaic was launched, I stopped all my other research and concentrated on the web
- People said that there was nothing new in the web, and it was not worth academic research
- My answer was “you don't understand, it will be in every home!”

Let's talk about Search

# Good results are (and should be) taken for granted



griffin music palo alto



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▶ [Gryphon Stringed Instruments - Fine guitars, acoustic and electric ...](#) ☆

Sep 8, 2010 ... Most **music** stores have sales all the time while Gryphon is famous for not having them, ... **Palo Alto**, California 94306 650.493.2131 ...

[www.gryphonstrings.com/](#) - [Cached](#) - [Similar](#)

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[The Gryphon Advantage](#)

[Nylon String Guitars](#)

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[Ukuleles](#) ☆

at the corner of Park and Lambert **Palo Alto**, California 94306 650.493.2131. Toll Free: 888.493.2131 ... New Maui Music All Koa Concert Longneck ...

[www.gryphonstrings.com/.../instrument\\_page.php?...](#) - [Cached](#) - [Similar](#)

[Guitarists' pick / Gryphon, a laid-back Palo Alto shop that's ...](#) ☆

Jul 20, 2001 ... Ah, but **Palo Alto** has the antidote to those overwhelming megastores. ... "The best way to compete with large **music** chains is to be as ...

[articles.sfgate.com/.../17610151\\_1\\_guitars-and-amplifiers-chain-stores-acoustic](#) - [Cached](#)

[Charles B. Griffin](#) ☆

Charles B. Griffin. blog, **music**, and information about the American composer .... **PALO ALTO** Saturday, June 19, 2010; 8 PM, St. Mark's Episcopal Church, ...

[www.charlesgriffin.net/](#) - [Cached](#) - [Similar](#)

# Search is hard, very hard

- We strive to answer every question, in every language, in a personalized fashion, in less than 100 ms, for free
- Scale and diversity are almost beyond comprehension
- About ***one third of all unique queries*** that we get in any given day, we have never seen before!
- **Expectations and needs will continue to grow**

# The results page has to be...

Lightning fast

---

Most relevant

---

Most comprehensive

---

Freshest

---

But even that's not enough

The real goal should always be  
**to solve the user's problem**

if users can't spell, it's our problem

if they don't know the syntax of search, it's our problem

if they don't know what words to use, it's our problem

if there is not enough content on the web, it's our problem

if they can't speak the language, it's our problem

if the web is too slow, it's our problem

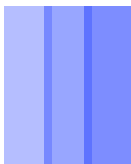
**We look at the **WHOLE** problem**

# Examples of what goes into the algorithm

- **Language:** We know that *child care* is very similar to *childcare* and to *day care*. We know that *Mexico* does not match *New Mexico*
- **Time:** We can figure out how time sensitive your results should be
- **Place:** We know that a day care in Menlo Park may be a good result when you're looking for a day care in Palo Alto
- **Context:** We know that Dr is a doctor in “Dr Zhivago” and a drive in “Rodeo Dr.”
- **You:** Personalized search

# Give me what I need, not what I said...

- A funny example: [how many calories in a pound?]
- Strictly speaking, the correct answer is  $9 \times 10^{15}$ 
  - The question is about conversion of mass (pound) to energy (calories), and there is a formula for that (which the Google calculator used)
- But this is most likely not what the user had in mind



We use data that is not on the web



alaska 301



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## Alaska Airlines Flight 301

On-time - departs in 7 hours 14 mins

SFO 

SEA

Departs San Francisco,  
Monday, June 16

Arrives Seattle,  
Monday, June 16

Time	Terminal	Gate
6:15 PM	1	22

Time	Terminal	Gate
8:10 PM	N	15

Showing airport times

### Alaska Airlines (AS) #301 FlightAware

[flightaware.com/live/flight/ASA301](https://flightaware.com/live/flight/ASA301) ▾ FlightAware ▾

Alaska Airlines (AS) #301 Flight Tracker (ASA301) Flight Tracker (en route flights, arrivals, departures, history) with live maps and aircraft photos.

# This was the top regular result for [alaska 301]

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## Alaska 301 To Seattle

 ALL SIZES

We found 237 photos matching [alaska 301](#). Click "search" above to see!

Uploaded on June 5, 2008  
by [asmythie](#)

**asmythie's photostream**


6,482 uploads

Tags

- mobile
- samsung a900
- PlanePix

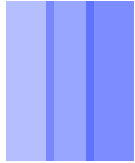
Additional Information

 Some rights reserved

 Anyone can see this photo

- Taken with a [MSM6500 SPH-A900](#)
- [More properties](#)
- Taken on June 5, 2008
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We can understand the use of language

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## ► Learn to Fly Helicopters

Sponsored links

[GoldenGateHelicopters.com/Training](#)

Train in Robinson R22 or R44 for Rotorcraft Private - ATP License.

## Helicopter Pilot Training

[www.quantumhelicopters.com](#)

Nationally accredited, FAA approved Full service **training** center.

## West Valley Flying Club

[www.wvfc.org](#)

3 Locations in the SF Bay Area 36 Years of flight instruction

[Show map of 1901 Embarcadero Rd # 100, Palo Alto, CA 94303](#)

## Helicopter Schools and Flight Training Directory ☆

**Helicopter** Schools and **Pilot Training**. Looking for something different? Then **helicopter** school may be for you. Helicopters are widely used to monitor ...

[www.bestaviation.net/helicopter\\_schools/](#) - Cached - Similar

## Helicopter Piloting - Helicopter Aviation ☆

**Training** to become a **Helicopter Pilot**. If you are thinking about getting your helicopter license, there are a few things you may want to know first. ...

[www.copters.com/helo\\_pilot.html](#) - Cached - Similar

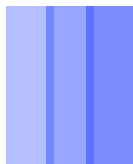
## Helicopter Flight Training - Bristow Academy Inc ☆

Part-time Evening Private **Pilot** Course Now Offered in Titusville ... Florida Tech, Bristow Academy Announce Partnership for **Helicopter** Flight **Training** ...

Tuition & Fees - Contact Us - Online Flight Schedule - Locations

[www.heli.com/](#) - Cached - Similar

## Midwest Helicopter - Homepage ☆



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acadolphus



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Did you mean: [acidophilus](#) Top 2 results shown

[Acidophilus - Wikipedia, the free encyclopedia](#) ☆

**Acidophilus** is a general name for a group of probiotics, often added to milk or sold as a capsule, which contains one or more of the following bacteria that ...

[en.wikipedia.org/wiki/Acidophilus](#) - [Cached](#) - [Similar](#)

[ACIDOPHILUS](#) ☆

Dr. Sears suggests: Take an **acidophilus** supplement, or try another probiotic like Culturelle®, one capsule daily. Culturelle contains another beneficial ...

[www.askdrsears.com/html/8/T080400.asp](#) - [Cached](#) - [Similar](#)

Results for: **acadolphus**

Your search - **acadolphus** - did not match any documents.

Suggestions:

Make sure all words are spelled correctly.

Try different keywords.

Try more general keywords.

Did you mean to search for: [acidophilus](#)

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Help Digestion- 40% Off Acidophilus Plus Limited Time Get Free Shipping

[www.Puritan.com/Acidophilus](#)

Puritan.com is [rated](#) ★★★★★

[Acidophilus: The Facts](#)

What Are The Health Benefits of Acidophilus? Read What Works & Why!

[www.JonBarron.org](#)

[Acidophilus](#)

Centrum®, Nature Made®, Schiff® Brand Names 30% - 70% Below Retail!

[www.medicalprovisions.com](#)

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Itchatukni Springs



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▶ [Ichetucknee Springs State Park - Welcome to Florida State Parks](#) ☆

Welcome to **Ichetucknee Springs** State Park. The crystalline Ichetucknee River flows six miles through shaded hammocks and wetlands before it joins the Santa ...

[Photo Gallery](#) - [About the Park](#) - [Activities](#) - [Additional Info](#)

[www.floridastateparks.org/ichetuckneesprings/](http://www.floridastateparks.org/ichetuckneesprings/) - [Cached](#) - [Similar](#)

[Ichetucknee River and Ichetucknee Springs - Tubing, Camping ...](#) ☆

Online guide to the beautiful Ichetucknee River and **Ichetucknee Springs** in Fort White, Florida. Tubing, camping, swimming, canoeing, kayaking, and more fun ...

[River Tubing](#) - [Park Information](#) - [Park Pictures](#) - [Local Camping](#)

[www.ichetuckneeriver.com/](http://www.ichetuckneeriver.com/) - [Cached](#) - [Similar](#)

Results for: **Itchatukni Springs**

[First half of '09, all went as planned - Clara South's MySpace Blog |](#) ☆

Dec 8, 2009 ... **Itchatukni Springs** was amazing as well. You could go free diving down to the spring where the water is seeping from the ground and it's so ...

[blogs.myspace.com/index.cfm?fuseaction=blog.view...blogId...](http://blogs.myspace.com/index.cfm?fuseaction=blog.view...blogId...) - [Cached](#)

[Clara South's MySpace Blog |](#) ☆

**Itchatukni Springs** was amazing as well. You could go free diving down to the ...

[blogs.myspace.com/claraissocool](http://blogs.myspace.com/claraissocool)

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► [craigslist: los angeles classifieds for jobs, apartments ...](#)

**craigslist** provides local classifieds and forums for jobs, housing, for sale, personals, services, local community, and events.

Search craigslist.org

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► [craigslist: california classifieds for jobs, apartments, personals ...](#)

**craigslist** > california. choose the site nearest you (or suggest a new one): SF bay area · bakersfield · chico · fresno / madera · gold country ...

[geo.craigslist.org/iso/us/ca](#) - [Cached](#) - [Similar](#)

Results for: **cragfl:ist**

[The Hoboken Journal: Das ist Kaput!- Gothic Cabinet Craft Furniture](#)

Jul 12, 2010 ... Das **ist** Kaput!- Gothic Cabinet **Craft** Furniture. Another business in Hoboken is going under, Gothic Cabinet **Craft** Furniture at 216 Washington ...

[thehobokenjournal.blogspot.com/.../das-ist-kaput-gothic-cabinet-craft.html](#) - [Cached](#)

[Selling list \(40x craft pack, scs and torches\) - Diablo 3 & Diablo ...](#)

4 posts - 3 authors - Last post: Aug 28

Selling **list** (40x **craft** pack, scs and torches) Europe Standard - Ladder.

[diablo.incgamers.com/forums/showthread.php?t=778475](#) - [Cached](#)

[Exclusive: Track List From Brian Eno's Upcoming Album, Small Craft ...](#)

Aug 23, 2010 ... Innovative musician Brian Eno has gone through several evolutions over the



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president eisenor



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[Dwight D. Eisenhower - Wikipedia, the free encyclopedia](#)

As **President, Eisenhower** concluded negotiations with China to end the Korean War. ....

Wernher von Braun briefs **President Eisenhower** in front of a Saturn 1 ...

[Early life and family](#) - [Early military career](#) - [World War II](#)

[en.wikipedia.org/wiki/Dwight\\_D.\\_Eisenhower](https://en.wikipedia.org/wiki/Dwight_D._Eisenhower) - [Cached](#) - [Similar](#)

[Dwight D. Eisenhower | The White House](#)

Republican emissaries to his headquarters near Paris persuaded him to run for **President** in 1952. "I like Ike" was an irresistible slogan; **Eisenhower** won a ...

[www.whitehouse.gov/about/presidents/dwightdeisenhower](http://www.whitehouse.gov/about/presidents/dwightdeisenhower) - [Cached](#) - [Similar](#)

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[EMC Update: Nova Scotia Edition](#)

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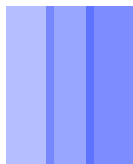
Newest Maritimes FSA Team Member Doug **Eisenor**. As was recently announced in the Update by EMC **President** and General Manager Al ...

[wcm.pavliks.com/WCMAdmin/Images/.../NS\\_Volume02Issue05.pdf](http://wcm.pavliks.com/WCMAdmin/Images/.../NS_Volume02Issue05.pdf)

[NEWS - TROMADANCE!](#)

David Gregory (Director, Plague Town / **President**, Severin Films) Frank H Woodward (Director Lovecraft: Fear of the Unknown) Jason **Eisenor** (Sundance Featured ...

[tromadance.com/past\\_years/2009/index.php](http://tromadance.com/past_years/2009/index.php) - [Cached](#)



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7 posts - 5 authors - Last post: Jan 3, 2008

[Archive] [How to change laptop screen brightness?](#) General Hardware.  
[icrontic.com](#) > > [Tech: Hardware](#) > [General Hardware](#) - [Cached](#) - [Similar](#)

[How do I adjust my brightness or contrast on my laptop?](#)

How do I **adjust** my **brightness** or contrast on my **laptop**? ... Finally, laptops only enable users to only **adjust** the **brightness** of their **screen**. ...

[www.computerhope.com/issues/ch000594.htm](#) - [Cached](#) - [Similar](#)

[How to change monitor brightness, contrast, etc? \[Archive ...](#)

15 posts - 12 authors - Last post: Apr 17, 2007

I have a Sony Viao **Laptop**. I was able to **change** the brightness on my ... The **screen brightness** settings are not listed in the Gnome Power ...

[ubuntuforums.org](#) > ... > [Hardware & Laptops](#) - [Cached](#) - [Similar](#)

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## [Converting PDF Documents to Microsoft Word - Tips](#)

May 12, 2005 ... I had a scanned **pdf** doc from a website that I needed to **convert** to a **word doc** for... In order to **convert a PDF into Word** you must have the ...

[www.pdfzone.com/.../Converting-PDF-Documents-to-Microsoft-Word/](#) - [Cached](#) - [Similar](#)

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How can I **convert a PDF** document to a **Word file** for simple editing? ... Can I copy and paste content in a **PDF** document **into** a new Excel or **Word file** without ...

[www.pdfzone.com/c/a/Tips/Convert-PDF-to-Word/](#) - [Cached](#) - [Similar](#)

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The **Post Office®** for **foreign currency exchange** and American Express Travellers Cheques at 0% commission. Order online. Free home delivery.

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The **Post Office®** can help with all your travel essentials including travel insurance, **foreign currency** and our passport check and send service. ...

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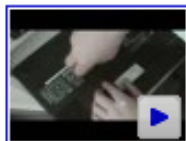
## Videos for how to change memory in laptop



[How to Install Laptop Memory](#)

3 min 12 sec - Jan 18, 2007

[www.youtube.com](http://www.youtube.com)



[Laptop RAM Change](#)

4 min 39 sec - Jan 22, 2008

[www.youtube.com](http://www.youtube.com)

## Installing laptop memory

Complete info on installing **Laptop Memory** also includes complete guide to all other computer **memory**, **ram** upgrades, **memory** installation, find the best place ...

[www.computermemoryupgrade.net/installing-laptop-memory.html](http://www.computermemoryupgrade.net/installing-laptop-memory.html) - [Cached](#) - [Similar](#)

## Upgrading Laptop Memory - Illustrated how to upgrade laptop memory

Photo and video illustrated guide to **laptop memory** upgrades on different **laptop** models.

[www.fonerbooks.com/laptop\\_2.htm](http://www.fonerbooks.com/laptop_2.htm) - [Cached](#) - [Similar](#)

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## [How to switch between monitors in Vista?](#)

Aug 3, 2009 ... I'm running Vista Ultimate and what I want to do is **switch between monitors** easily. Laptops generally have a Fn key that does this easily ...

[www.autohotkey.com/forum/topic47183.html](http://www.autohotkey.com/forum/topic47183.html) - [Cached](#) - [Similar](#)

## [Using Multiple Monitors with Windows XP](#)

Jul 26, 2004 ... Additionally, each of my three **monitors** uses a different resolution, so windows **change** size as I drag them **between** displays. ...

[www.microsoft.com](http://www.microsoft.com) > ... > [Computer Setup and Maintenance](#) - [Cached](#) - [Similar](#)

## [How to Move Items Between Monitors | eHow.com](#)

How to Move Items **Between Monitors**. If you have two or more **monitors** connected to your computer, you may want to move items **between** them.

[www.ehow.com](http://www.ehow.com) > ... > [Computer Hardware](#) > [Computer Monitors](#) - [Cached](#) - [Similar](#)

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Mar 27, 2007 ... Turn off the **power** to the **outlet** at the fuse box or circuit breakers. ... A salesperson can help you find the correct **outlet** to **replace** the ...

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gandhi bio



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# Unless it's warfare – Content counts!



bio warfare



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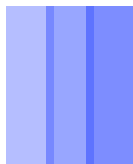
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And we're having fun!



recursion



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[Recursion -- from Wolfram MathWorld](#) ☆

Oct 11, 2010 ... A **recursive** process is one in which objects are defined in terms of other objects of the same type. Using some sort of recurrence relation, ...

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Sep 27, 2010 ... Definition of **recursion**, possibly with links to more information and implementations.

[xw2k.nist.gov/dads/HTML/recursion.html](#) - [Cached](#)

[Recursion](#) ☆

**Recursion** simply means applying a function as a part of the definition of that same function.

Many of today's algorithms are not based on structure, they are based on data, which in turn is based on people

Learning from user data  
is the key

# Data will cheat you whenever it can

- Data is useless -- unless you know how to read it
- Important factors are almost always missing
- It often addresses short term only
- You can always benefit from more of it..

# Analogy to medical research

- Moving from beliefs and opinions to science saved millions and made medicine what it is today.
- Many of us are alive today because of the use of controlled experiments in medicine
- But there is still not enough data
- Many medical decisions are still made based on instincts
- Worse, 50-75% of research results cannot be replicated



We see knowledge  
through small facts







We need a bigger picture from many angles





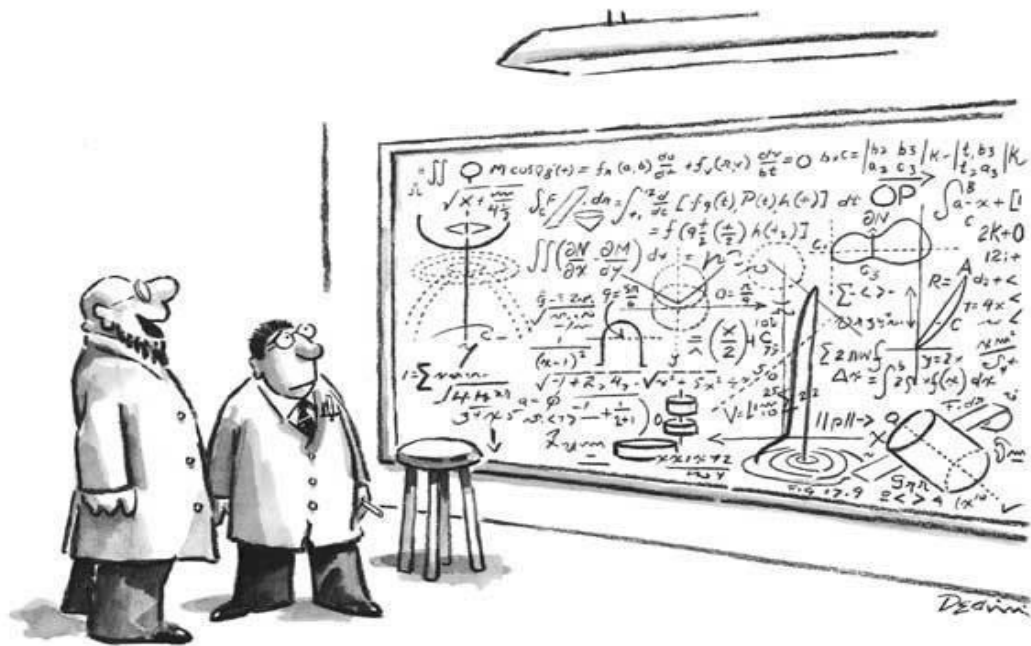
## From dots to wisdom

- If you think of facts as dots, we now have access to more dots than ever
- Actually more dots than anyone can imagine
- But we still need to **connect the dots**
- Connecting those dots might require new methods

Data  Information 

Information  Knowledge 

Knowledge  Wisdom 



"Hey, no problem!"



"Hey, no problem!"

So how to think big?

If you have to ask you'll never know

Louis Armstrong