Computer Science:

Where is it coming from and where is it going to?

CS Immigration Course – Fall 2022
Slides Developed by Kemal Oflazer

Education: Where are we?

The Definitive Statement on Education

Education Level	What You Think You Know	How You Act	What You Learn

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College	Just About Everything	Like You Know Quite A Lot	That There Are Things You Don't Know
Graduate School (Masters)	Some Things	Like You Know A Lot	That You Really Don't Know Much
Graduate School (PhD)	Nothing	Like You Don't Want People To Know That You Know Nothing	How Huge And Vast An Amount You Really Don't Know

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Final word on Education

- "No one should escape our universities without knowing how little s/he knows" - Robert Oppenheimer – Physicist, Scientific Director of the Manhattan Project

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Outline

- ~~Introduction on Education~~
- What is Computer Science (CS)?
- What skills are needed for a Computer Scientist?
- What will you work on as a Computer Scientist?
- Evolution of Computing
- Future of Computing

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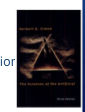
The Burning Question

- What is Computer Science?
- What is science?
  - Science is the study and understanding of the possible (and beyond.)
  - Science is mainly analytical, that is,
    - it tries to analyze, understand and describe nature
    - and also the unnatural,
      - Beyond a certain complexity, artifacts have complex behavior
      - Herbert Simon, The Sciences of the Artificial
  - But Computer Science also involves a lot of engineering.
    - Yes, you can tell your grandma, you will be an engineer and she will be proud (☺)



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What is Computer Science?

- Computer Science is the study of how information is created, processed and communicated.

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What is Information?

- Hard to say!
- Added value on top of "data"
- You know when you have it (and when you don't have it), but
- You can't touch it!
- It takes energy, time, money to produce it, but yet it is very abstract.
- You can store it for later use (if you don't, you lose it permanently)
- You can measure it! (it has a unit-- really!)

Wht s nfrmtn?

- Hrd t sy!
- Ddd vl n tp f dt
- Y knw whn y hv t (nd whn y dn't hv t), bt
- Y cn't tch t!
- t tks nrgy, tm, mny t prdc t, bt yt t s vry bstrct.
- Y cn str t fr ltr s (f y dn't, y ls t prmnntly)
- Y cn dplct t, y cn sll t r y cn by t.
- Y cn msr t! (t hs a nt – Rlly!)

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a i loaio?

- a o a!
- Ae aue o o o aa
- ou o e ou ae i (a e ou on a i), u
- ou a ou i!
- l ae ee, ie, oe o oue i, u e i l e aa.
- ou a oe l o ae ue (l ou o, ou oe l eae)
- ou a eaue i! (l a a ui)

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whatisinformation

- hardtosayAddedvalueontopofdataYouknowwhenyouhaveitandwhenyoudonthaveitbutyoucanttouchitittakesenergytimemoneytoproduceitbutyetitisveryabstractyoucanstoreitforlaterusei fyoudontyouloseitpermanentlyyoucanmeasureititihasaunitreally

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What is information?

- Content vs. Representation

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What is information?

- Content vs. Representation
- Content is “music”, an arrangement of notes

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What is information?

- Content vs. Representation
- Content is “music”, an arrangement of notes
- Representation
  - Music scores
  - Air waves – “Sound”
  - Sequence of digital representations of the “sound”
  - Wav file, mp3, AAC
- Information is in the content, NOT in the representation.
  - Representation just carries or communicates it
  - But we operate on the representation – or data

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What is information?

- There is even a mathematical definition in the science of "Information Theory"
- The definition basically says "The more unexpected you perceive an event to be, the more information you 'gain' when you observe the event happens"
  - Information gained in observing an event e is $-\log_2 P(e)$ bits

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What is Computer Science?

- The fundamental question underlying all computer science is:

What processes can be automated and how do we automate them (using computers)?

What is Computer Science?

- Computer Scientists build information processing systems by bringing together
  - hardware
  - software

  so that the system
  - works (i.e. has (almost) no bugs)
  - is fast, maintainable, robust, and affordable.
- Computer Scientists build, experiment with, and evaluate prototype systems that incorporate new
  - ideas,
  - technologies,
  - approaches

  to solve old or new problems.

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Skills of a good computer scientist

- Good, open mind
  - Things are changing faster that you think
  - Rate of change of change is increasing
    - For calculus geeks: second derivative is increasing (☹)
    - Accelerating change
- Common sense
  - Engineering, like politics, is the art of compromises
- Ability to analyze
  - Crucial!
- Ability to communicate
  - Written, verbal, bi-lingual (at least!)
  - That is why you have to be good in reading AND writing!

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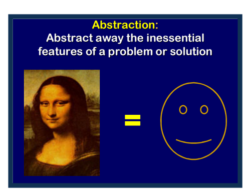
Skills of a good computer scientist



- **Ability to abstract**
  - understand the detail, but always in relation to the whole,
  - know how to forget or avoid the details, when necessary
- **Ability to synthesize**
  - Crucial

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Skills of a good computer scientist

- Ability to learn and generalize
  - from successes and failures
- Ability to make trade-offs
  - you do not need a multi-core 3.7 Ghz 8-core super duper system if all you need to do is word processing!
    - Intel thinks otherwise (☺)
- Ability to justify hard decisions
- Very good understanding of fundamental theory and techniques of the field.
  - Mathematics, theoretical computer science, algorithms, data structures, hardware, operating systems, programming, ….
  - **That is why you are here**

Skills of a good computer scientist

- Understanding the problem, requirements, specifications
- Decomposing problems into manageable parts (Always!)
- Good understanding of data and its organization
- Knowing how to design and/or select efficient algorithms
- Synthesis
  - programming in the small,
    - you writing your toy code
  - programming in the large -- software engineering
    - 1000s people writing MacOS X, Windows, Android, Chrome, IOS Linux, etc.

Skills of a good computer scientist

- Understand what can be feasibly computed
  - You have time to wait for the results
- Understand what can NOT be feasibly computed
  - You do not have time to wait for the results which will take another few billion years
- Understand what can never be computed

Scooping the Loop Snooper

an elementary proof of the undecidability of the halting problem ….

No program can say what another will do.
Now, I won't just assert that, I'll prove it to you:
I will prove that although you might work til you drop,
you can't predict whether a program will stop.

You can never discover mechanical means
for predicting the acts of computing machines.
It's something that cannot be done. So we users
must find our own bugs; our computers are losers!

by Geoffrey K. Pullum
Stevenson College
University of California
Santa Cruz, CA 95064

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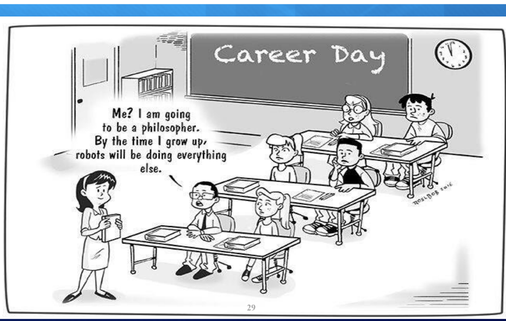
What will you be when you grow up?



What will you be when you grow up?

- Job opportunities
  - Software Companies
  - IT Departments
    - Banks (Web development, security, speech processing, databases)
    - Manufacturing (Databases, process automation, simulation, vision, robotics, AI, machine learning)
    - Media (Graphics, Web development, text processing, information retrieval, NLP)
    - Telecom (Networking, security)
    - General (System Management)
  - Start-up companies
  - Research Centers (e.g. QCRI, QBRI, QEERI, Google, Microsoft Research, Baidu, Facebook, Amazon, etc.)
  - Tech Companies (Twitter, Bosch, Salesforce, Dropbox, LinkedIn, Uber, etc.)

What will you be when you grow up?

- Graduate Study
  - Master of Science (M. Sc.) (1/2 years – Advanced Courses + Research+Thesis)
  - Doctor of Philosophy (Ph. D.) (4-6 years – more advanced courses + original research+Thesis)
- Job opportunities
  - Faculty Members/Researchers at Universities
  - Researchers at advanced research labs
  - Research policy managers

Specialization

- An expert is someone
  - who knows more and more
  - about less and less, until
  - s/he knows everything about nothing (☺)

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The Evolution of Computing

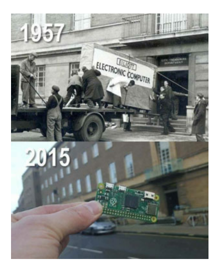
- Where are we coming from?
  - You probably do not have a good feel of what life in the computerland was like from the 1960's through 2000's.
  - Hell – you probably can not imagine a world without smartphones, Internet, Facebook, Instagram, etc.
- Life was very different 40-50 years ago. (and I know you do not care!)
  - But most everything you see now were envisioned at least 40-50 years ago, if not more!

The Evolution of Computing

- 1950's computer

The Evolution of Computing

- Then and now!

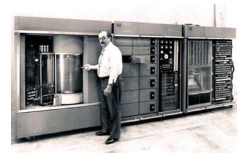


The Evolution of Computing

- 1950's hard disk drive

The Evolution of Computing

- 1950's hard disk drive

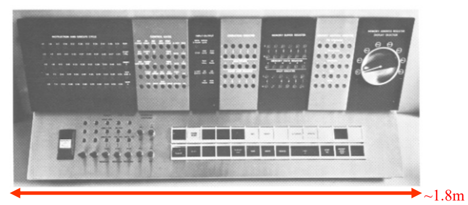


A sample history of computer technology

- 1960's:
  - 100 KHz Machines (IBM 1620),
  - 20-30 KB Memory,
  - Punched Card Input,
  - Teletypes, Line Printers,
  - 10-20 MB Disks
  - Computers consumed kilowatts, need serious AC cooling,
  - **ARPANET, the precursor to Internet, starts about here also.**
  - **"Deep Learning" also starts here – Perceptrons!**
  - **AI actually started in late 1950's**
    - **Dartmouth Conference (1956)**

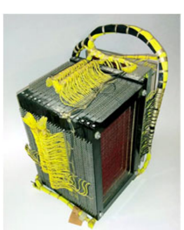
A sample history of computer technology

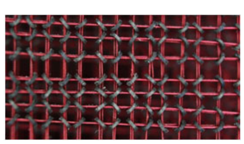
- 1970 IBM 1620
  - The first computer I wrote a program for



A sample history of computer technology

- Magnetic Core Memory (4096 bytes)





A sample history of computer technology

- Punched Card Input? What IS that?

A personal history of computer technology

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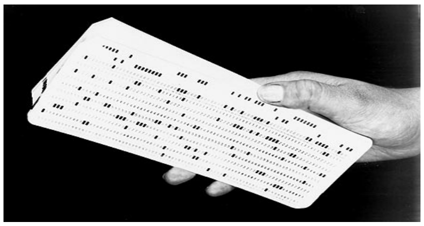

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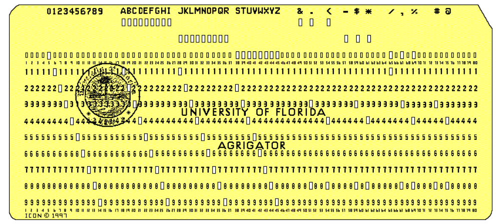


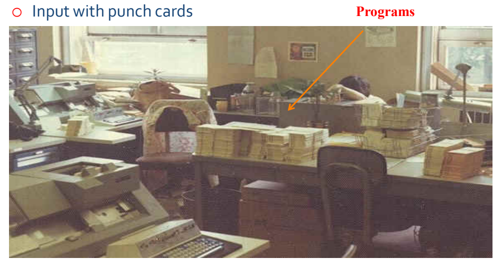
A sample of computer technology

- Input with punch cards

A sample history of computer technology

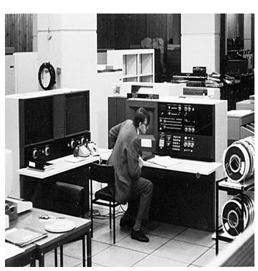
- Input with punch cards

Programs

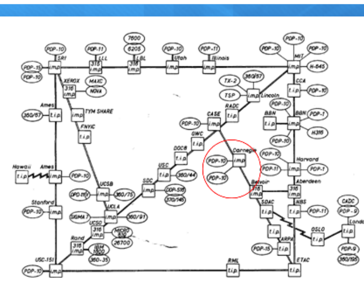


A sample history of computer technology

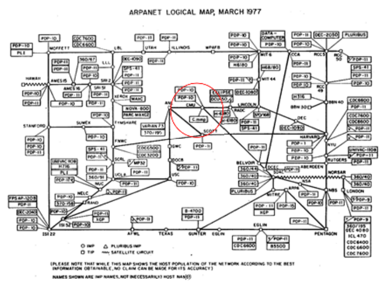
- 1970's: 500 KHz Machines (IBM 360/370), 100-500 KB Memory, Video Terminals
- 1975 IBM 370
- 392 Kilobytes, 500 Khz
- Timesharing systems



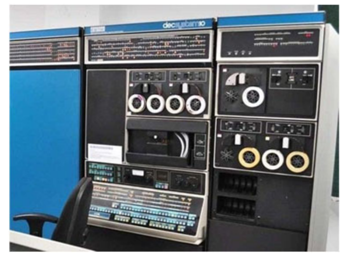
ARPANET circa 1973



ARPANET circa 1977

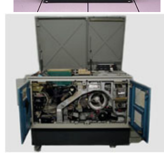


DEC 10 at CMU late 1970's & early 1980's



A sample history of computer technology

- Early 1980's:
- 1Mhz Machines (Vax 780), 1-2 MB Memory, CRT Terminals (9600 Baud serial lines), ethernet
- 50-100 MB Disks,
- Early laser printers: Xerox Dover printer,
  - Printed 1 page a second,
  - Cost 300,000 dollars



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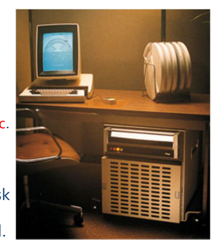
A sample history of computer technology

- Mid 80's:
- Xerox Alto Workstation
  - The first real personal computer!
  - Steve Job's is famously rumored to have seen this and then built the Mac.
- 128KB RAM, 5.8 MHz Processor
- Interchangeable **2.5MB** personal disk
- Only 2000 units were ever produced.
  - Cost $10,000 1980 dollars to build = $31000 in 2019 dollars



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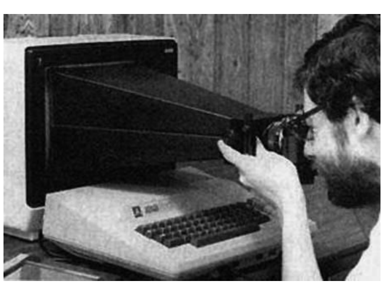
Screen shots then



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Mobile Phones

- Mobile phones are actually quite old.
- First proof of concept mobile phone was built and demoed in 1973
- Publicly available in 1984 – expensive!

A personal history of computer technology

- Late 80's:
- Sun 1 - 4 Workstations
- 16 MB, 70 MegaHertz

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A sample history of computer technology

- Late 80's MacIntosh SE
  - 4 MB RAM 40 MB Disk, 20 Mhz
  - 3000 (1988) dollars = 6531 (2019) dollars
  - My first personal computer
- Through 90's,
  - Sun SparcStations
    - 32 MB – 1 GB RAM, 32 – 450 MHz
  - Various Macintoshes/Mac Laptops
    - 4 MB - 200 MB Ram, 32 – 233 Mhz
  - Various PCs
    - 1 MB – 1GB Ram, 266 – 750 MHz

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Apple Powerbook 170

- My first laptop
- **Released:** October 21, 1991 (Bought it in December 1991)
- **Price:** **$4,599** (≈**$8,750** in 2019)
- **CPU:** Motorola 68030, 25 MHz
- **Memory**: 40 MB disk, 4MB RAM
- Weighs several kilos, mechanical tracker
- Still functional – at least will boot

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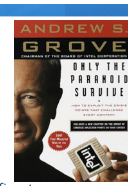
What is driving all this?

- Semiconductor Technology
- Paranoia (☺)
  - *Andrew S. Grove (Intel Chairman)*
    - Only the paranoid survive (1996)



- Theoretical breakthroughs
  - It turns out that these have provided the most significant improvement, but we rarely see it mentioned
  - If you discover a polynomial time algorithm for a problem not known to have one, your impact will be way more than any hardware improvement.

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Very Large Scale Integrated Circuit Technology

- Intel 8086 (1979)
- 29,000 Transistors
- 5 Megahertz
- The first microprocessor I built a computer with

Microprocessor based modular database processors

Authors: Esen A. Ozkarahan
Kemal Oflazer

Published in:
· Proceeding
VLDB '78 Proceedings of the fourth international conference on Very Large Data Bases - Volume 4
Pages 300-311

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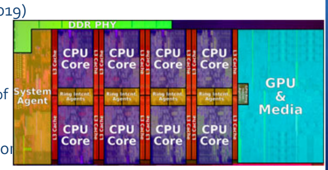
Very Large Scale Integrated Circuit Technology

- Intel Coffee Lake– (2019)
  - 8 Cores + GPUs
- ~6 billion transistors
  - 270,000 times that of 8086
- 4 – 4 GHz depending on the models



14 nm++ process
11 metal layers
~174 mm² die size

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Then this happens!
2019 – 1.2 Trillion Transistor Deep Learning Processor

- 462.25 cm² on a "wafer"
  - Compare with 435 mm² earlier
  - ~100 times larger
- 56 times larger than the largest GPU today
- Power consumption is not publicized
- But apparently water-cooled

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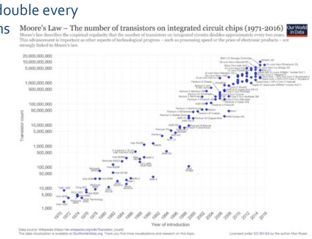
Very Large Scale Integrated Circuit Technology

- Moore's "Law"
  - Transistors double every 18-24 months



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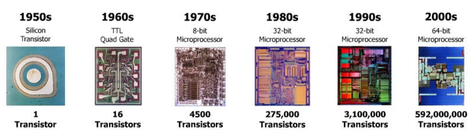
Moore's Law



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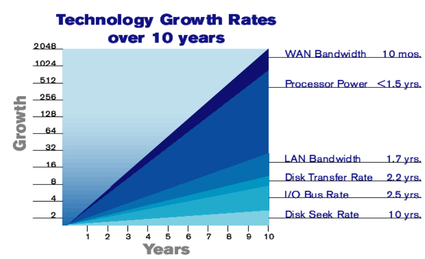
Other trends



Note that the Y axis is logarithmic, so these are exponential growths

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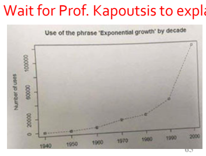
Exponential Growth

- It is good when it applies technological advances.
- Not so good when it applies to problem complexity.
  - There are legitimate problems that will take ~10^{1000} centuries to solve with the fastest computers and algorithms available.
    - Universe has been around for about 14 * 10^7 centuries!
  - Wait for Prof. Kapoutsis to explain you that!



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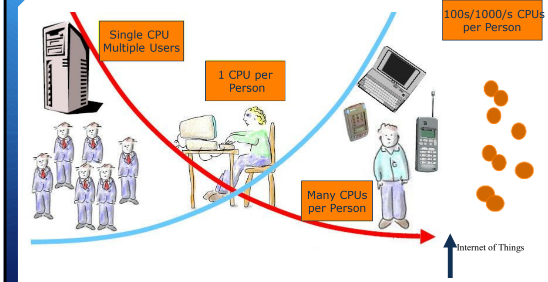
Where are we heading?

- "**Prediction is hard, especially about the future.**"
  Niels Bohr

Where we are heading?



Broadband Speed

- World Average is about 7.1 Mbit/s (2017)

Ranking position	Country	Mean Download Speed
1	Singapore	60.39
2	Sweden	46.00
3	Denmark	43.99
4	Norway	40.12
5	Romania	38.60
6	Belgium	36.71
7	Netherlands	35.95
8	Luxembourg	35.14
9	Hungary	34.01
10	Jersey	30.90
11	Switzerland	29.92
12	Japan	28.94
13	Latvia	28.63
14	Taiwan	28.09
15	Estonia	27.91
16	Spain	27.19
17	Republic of Lithuania	27.17
18	Andorra	27.14
19	Hong Kong	26.45
20	United States	25.86
21	Slovakia	25.30
22	Madagascar	24.87
23	France	24.23
24	Finland	24.00
25	Germany	24.00

Typical home internet in SFO in 2019

Happening Now

- Early 2020s:
  - Cars, appliances, telephones, everything have lots computing power somewhere
    - Car service is really SW upgrade mostly
  - Essentially infinite bandwidth (and wireless too),
  - Speech and visual interfaces, coming
    - Siri, Kinect, Google Now, Alexa
    - Dictation is widely available on mobile platforms
  - Wearable computers
    - Smart Watches
    - Virtual Reality
    - Google/Apple Glass
  - Trackers
    - Fitbit, Apple Watch, Smart Implants (e.g. Cont. Glucose Monitors)
  - Deep Learning/Machine Learning/AI Tsunami

Computational Journalism!
Computer writing news stories

INVESTING 9/24/2014 @ 9:00AM | 369 views

Forbes Earnings Preview: Nike

By Narrative Science

+ Comment Now + Follow Comments

Nike reports its first-quarter earnings on Thursday, September 25, 2014, and the consensus earnings per share estimate is 88 cents per share.

The consensus estimate has fallen over the past three months, from 93 cents. For the fiscal year, analysts are expecting earnings of $3.39 per share. Revenue is projected to eclipse the year-earlier total of $6.97 billion by 12%, finishing at $7.83 billion for the quarter. For the year, revenue is projected to roll in at $30.36 billion.

Over the last four quarters, income has increased 11% on average year-over-year. In the second quarter, the company saw its greatest gain in income, when it increased 40% from the year-earlier quarter.

Over the last four quarters, revenue has increased 8% on average year-over-year. In the third quarter, the company saw its greatest gain in revenue, when it increased 13% from the year-earlier quarter.

Then this happened

On Extractive and Abstractive Neural Document Summarization with Transformer Language Models

Sandeep Subramanian[1,2,3,*], Raymond Li[1,*], Jonathan Pilault[1,2,4,*], Christopher Pal[1,2,4,5]
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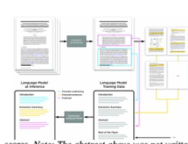
Abstract

We present a method to produce abstractive summaries of long documents that exceed several thousand words via neural abstractive summarization. We perform a simple extractive step before generating a summary, which is then used to condition the transformer language model on relevant information before being tasked with generating a summary. We show that this extractive step significantly improves summarization results. We also show that this approach produces more abstractive summaries compared to prior work that employs a copy mechanism while still achieving higher rouge scores. *Note: The abstract above was not written by the authors, it was generated by one of the models presented in this paper.*

Introduction



scores. *Note: The abstract above was not written by the authors, it was generated by one of the models presented in this paper.*

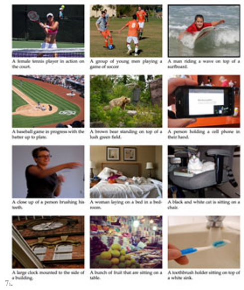
Deep Learning

- Starts in 1960's
  - Fades after computational limits are proved.
- Popular in 1980's and early 1990's
  - Fades again due to scalability problems
- Comes back with a vengeance in 2010's when
  - Cheap computing power
  - Specialized hardware (GPU, TPU)
  - Lots of data

  are available.
- You really need to be deeply proficient in **multi-variate calculus, probability and statistics** to understand how to build one of these and understand how they work.

Machine Learning/Deep Learning/AI

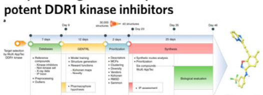
- Radically and quickly changing everything
  - Medicine,
  - Security/Surveillance
  - Language Translation
  - Image Captioning
  - Autonomous Cars
  - Investing
  - Education
  - Medicine
  - Hollywood



Deep Learning in Drug Discovery

- Hot off the presses

Deep learning enables rapid identification of potent DDR1 kinase inhibitors



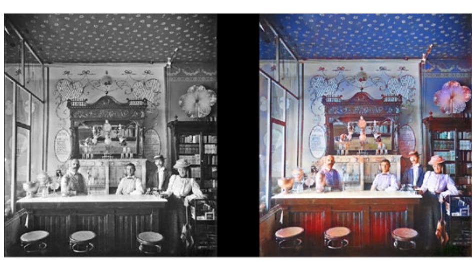
We have developed a deep generative model, generative tensorial reinforcement learning (GENTRL), for de novo small-molecule design. GENTRL optimizes synthetic feasibility, novelty, and biological activity. We used GENTRL to discover potent inhibitors of discoidin domain receptor 1 (DDR1), a kinase target implicated in fibrosis and other diseases, in 21 days. Four compounds were active in biochemical assays, and two were validated in cell-based assays. One lead candidate was tested and demonstrated favorable pharmacokinetics in mice.

- Nature, 2 September, 2019, https://www.nature.com/articles/s41587-019-0224-x

Deep Learning in Medicine

- Hot off the presses (Forbes, Sept 12 2019)
- **"Artificial Intelligence Detects Heart Failure From One Heartbeat With 100% Accuracy"**
  - Doctors can detect heart failure from a single heartbeat with 100% accuracy using a new artificial intelligence-driven neural network.
  - That's according to a recent study published in Biomedical Signal Processing and Control Journal, which explores how emerging technology can improve existing methods of detecting congestive heart failure.
  - Led by researchers at the Universities of Surrey, Warwick and Florence, it shows that AI can quickly and accurately identify CHF by analyzing one electrocardiogram (ECG) heartbeat.

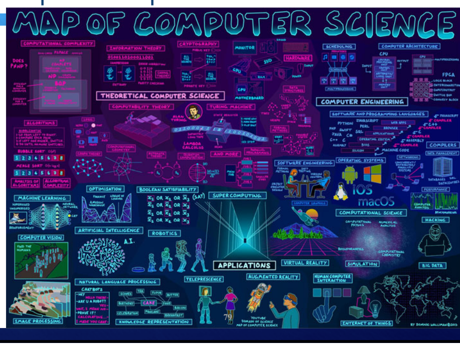
Coloring old B & W Images and Movies



Quantum Computing

- New model of computing based on quantum states of subatomic particles
  - Another reason to take your physics courses very seriously!
- Big push by tech companies and countries to "crack" this and build the first production quantum computer
  - Quantum supremacy
- Quantum computing will bring speed-ups to many algorithms and will up-end many applications starting with encryption.
- If you plan to do graduate study, this may be an interesting area.

Map of Computer Science



Further ahead

- If Moore's Law keeps up for a longer time, how do
  - CPU power
  - Memory density

  grow.
- Some walls have already been hit.
  - Switch to multi-core structures
  - That is why we have the 15-210 Parallel Algorithm and Data Structures course
- What do we do with all this computing power?
- What would we do with all this memory?
  - Suppose you could "remember" and quickly access everything you see, hear, touch, smell, (maybe even think of (☺)).

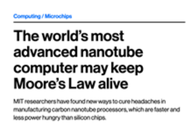
Further Ahead

- Internet of Things or computing-by-the-kilo (☺) – security, privacy, robustness
- Forbes Mag. Aug 2019 ⟶
- Any (CS) student who does not take at least 2-3 AI-related courses will most likely be handicapped.


Software Ate The World, Now AI Is Eating Software

Moore's Law revisited

- The death rumors of Moore's Law have been exaggerated
- But silicon is pretty much done.
- Specialized architectures are popular
  - GPUs
  - TPUs
- MIT Technology Review, Sept 2019


Computing / Microchips

The world's most advanced nanotube computer may keep Moore's Law alive

MIT researchers have found new ways to cure headaches in manufacturing carbon nanotube processors, which are faster and less power hungry than silicon chips.

Some grand challenges in computing

- Modelling and fast simulation of living biological structures
  - Cells, Brain, Organs
- Practical ubiquitous computing
  - Computers everywhere but hidden
- Capture, access and process a lifetime of human sensory input and memory
- Understand the architecture of brain and mind
- Build robust and dependable computer systems
- Realize quantum, chemical, biological computing
- Establish "computational thinking" as a fundamental skill in education (CS broadly is the new math!)

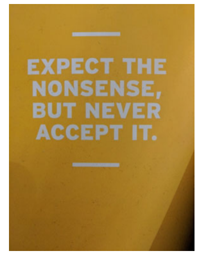
Outline

- ~~Introduction on Education~~
- ~~What is Computer Science (CS)?~~
- ~~What skills are needed for a Computer Scientist?~~
- ~~What will you work on as a Computer Scientist?~~
- ~~Evolution of Computing~~
- ~~Future of Computing~~

Final Words and Advice

- You will be living in a "bubble" for at least the next 4 years
  - Interacting with smart, hard-working people like yourselves
- But real world is quite different
- Adjusting could be VERY hard
  - Learn about the Dunning-Kruger effect
    - e.g. Watch https://www.youtube.com/watch?v=wvVPdyYeaQU
  - It will explain so much of the reality you will observe

So



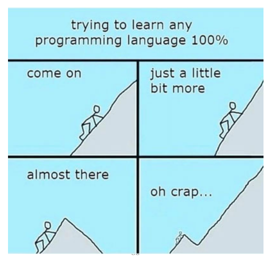
Final Words and Advice

- Develop a healthy appreciation of Humor
  - Especially Computer Humor – seriously!
    - Most of it is self-deprecating and takes the stress away (☺)
  - Better – work on computational humor,
    - develop systems that can laugh at a good joke – seriously!
    - If your system laughs at this – you will get a PhD
      - https://www.youtube.com/watch?v=SXn2QVipK2o

  - Here are some more examples of humor
  - If you do not get any/some of these – you will, in due time

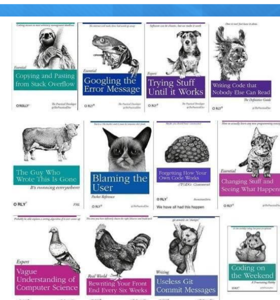
CS Humor

Your life for the next several years

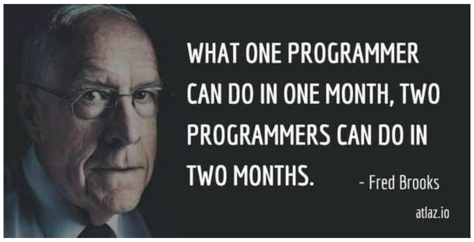


CS Humor

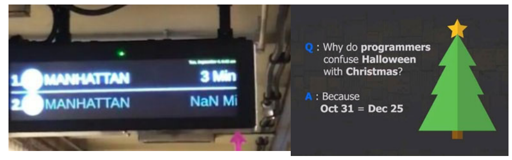
CS Humor
Books you should not be reading



CS Humor

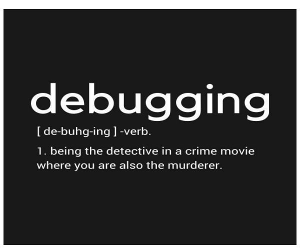


CS Humor

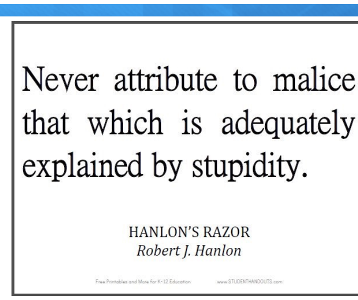


You will get these when you take 15-213

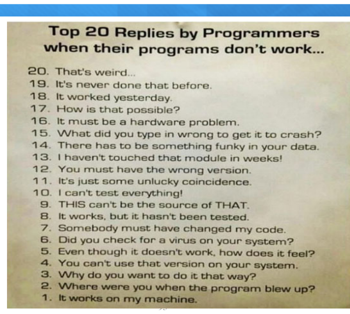
CS Humor



CS Humor



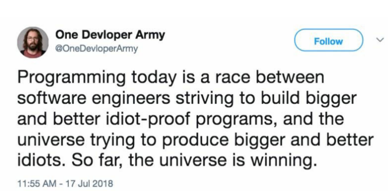
CS Humor



Top 20 Replies by Programmers when their programs don't work...

20\. That's weird...
19\. It's never done that before.
18\. It worked yesterday.
17\. How is that possible?
16\. It must be a hardware problem.
15\. What did you type in wrong to get it to crash?
14\. There has to be something funky in your data.
13\. I haven't touched that module in weeks!
12\. You must have the wrong version.
11\. It's just some unlucky coincidence.
10\. I can't test everything!
9\. THIS can't be the source of THAT.
8\. It works, but it hasn't been tested.
7\. Somebody must have changed my code.
6\. Did you check for a virus on your system?
5\. Even though it doesn't work, how does it feel?
4\. You can't use that version on your system.
3\. Why do you want to do it that way?
2\. Where were you when the program blew up?
1\. It works on my machine.

CS Humor




Thank you
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