Computer Science:

Where is it coming from and where is it going to

CS Immigration Course – Fall 2018

1

Education: Where are we?

The Definitive Statement on Education

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

2

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3

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High School	Everything	Like You Know Everything	How To Learn

4

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5

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6

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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

7

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You are here

We, the hopeless, are somewhere down there.

8

Education

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

9

Computer Science

- What is Computer Science?

10

Computer Science

- What is Computer Science?
- What skills does one need?

11

Computer Science

- What is Computer Science?
- What skills does one need?
- What will you learn here?

12

Computer Science

- What is Computer Science?
- What skills does one need?
- What will you learn here?
- What will you NOT learn here?

13

Computer Science

- What is Computer Science?
- What skills does one need?
- What will you learn here?
- What will you NOT learn here?
- What will you be when you grow up?

14

The Burning Question

- What is Computer Science?

15

The Burning Question

- What is Computer Science?
- What is science?
  - Science is the study and understanding of the possible (and beyond.)
  - Science is mainly analytic, 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

16

The Burning Question

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  - Science is mainly analytic, that is,
    - it tries to analyze, understand and describe nature
    - and also the unnatural,
      - Beyond a certain complexity, artifacts have complex behaviour
      - 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 (☺)

What is Computer Science?

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

What is Information?

- Hard to say!

19

What is Information?

- Hard to say!
  - You know when you have it (and when you don't have it), but

20

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  - You know when you have it (and when you don't have it), but
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21

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  - It takes energy, time, money to produce it, but yet it is very abstract.

22

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23

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  - You can't touch it!
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  - You can store it for later use (if you don't, you lose it permanently)
  - You can measure it! (it has a unit-- really!)

24

Wht s nfrmtn?

- Hrd t sy!
  - 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!)

25

a i loaio?

- a o a!
  - 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)

26

whatisinformation

- hardtosay
  - Youknowwhenyouhaveitandwhenyoudonthaveitbut
  - youcanttouchit
  - ittakesenergytimemoneytoproduceitbutyetitisveryabstract.
  - youcanstoreitforlateruseifyoudontyouloseitpermanently
  - youcanmeasureitithasaunitreally

27

What is Information?

وَلَم يَتَسَن عَلَى الْفَوْر الْاتِّصَال بِمُتَحْدّث بِاسْم وَزَارَة الدَّاخِلِيَّة لِلْتَّعْقِيْب

ولم يتسن على الفور الاتصال بمتحدث باسم وزارة الداخلية للتعقيب

The ministry of interior could not be reached for comments immediately.

28

What is information?

- Content vs. Representation

29

What is information?

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

30

What is information?

- Content vs. Representation
- Content is "music", an arrangement of notes
- Representation
  - Music scores
  - Air waves – "Sound"
  - Sequence of digital representation of the "sound"
  - Wav file, mp3, AAC
- Information is in the content NOT in the representation.
  - But we operate on the representation

31

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 it happens"

32

What is information?

- I suggest you read
  - The Information: A History, a Theory, a Flood by James Gleick
  - Published by Pantheon, March 2011

- "To grasp what information truly means—to explain why it is shaping up as a unifying principle of science—Gleick has to embrace linguistics, logic, telecommunications, codes, computing, mathematics, philosophy, cosmology, quantum theory and genetics. He must call as witnesses not only Charles Babbage, Alan Turing and Kurt Gödel, but also Borges, Poe and Lewis Carroll. There are few writers who could accomplish this with such panache and authority. Gleick, whose 1987 work Chaos helped to kickstart the era of modern popular science, is one."

  —Philip Ball, The Observer

33

What is Computer Science?

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

- Computer Science also involves engineering hardware and software systems that
  - Store
  - Transmit
  - Process

  information.

34

What is Computer Science?

- Computer scientists also do research on how to build systems:
  - that are new (incorporating new ideas and technology),
  - that solve an important problem hitherto unsolved satisfactorily,
  - that are "cheap" (so that they are affordable)

35

Building Systems

- 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.

36

Some important problems

- Recognizing human speech, or handwriting,
- Driving a car,
- Making investment decisions,
- Playing chess (DeepThought/DeepBlue), Go (DeepMind), Poker (CMU)
- Translating speech from one language to another (Google/Skype),
- Summarizing evening TV news, company financial sheets
- Writing news stories
- Piloting an airplane/helicopter
- Generating very realistic movies
- Answering questions in an expert domain (Watson!)
- Captioning images
- Searching through videos
- Telling a joke?
- Flagging fake news

37

Research

- Computer Scientists build, experiment with, and evaluate prototype systems that incorporate new
  - ideas,
  - technologies,
  - approaches

to solve old and new problems.

38

Technology

- Hardware Technologies
- Software Technologies
- Theoretical Results
- New Approaches

39

Technology

- Speech Recognition
- Computer Vision
- Understanding Natural Language
- Cryptography
- Internet
- Machine Learning
- Deep Learning
- Electronic Publishing
- Remote Sensing
- Sensor networks
- Blockchain
- Internet of Things

40

Technology

- Electronic Commerce
- Ubiquitous Computing (Computers everywhere but invisible)
- Convergence of mobile phone, PDA, internet access all in one device, wearable computers (your jacket is your computer!)

41

Technology

- Better user interfaces (recognize emotions, motions and gestures, read lips, etc.)
- Virtual Reality
- Entertainment technology
  - Special Effects

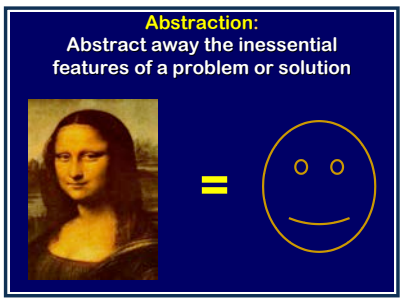
42

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!)

43

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

44

Skills of a good computer scientist

- Ability to learn and generalize
  - from successes and failures
- Ability to do 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, programming, ….

45

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 (hacking (☺)),
    - you writing your toy code
  - programming in the large --software engineering
    - 1000 people writing MacOS X, Windows, Android, Chrome, etc.

46

What will you learn in the CS program ?

- Computational Thinking
  - How do solve a problem using computation?
  - Programming
    - Sequential and Parallel, Imperative and Functional
- Basics of Computer Hardware/Operating Systems
- Basics of the Theory of Computation
- Theory and Practice of Programming Languages
- Algorithm Design and Analysis
- Computer Networks and Distributed Systems
- Artificial Intelligence/Robotics/Machine Learning

47

What you will NOT learn!

- You will NOT have courses on specific languages, or systems.
- You will NOT learn how to use specific packages like Visual Basic, MS Access or Mathematica or things like that.
- You will NOT learn how to assemble or network PC's.
- You will NOT learn about how to program on/for a specific platform.

48

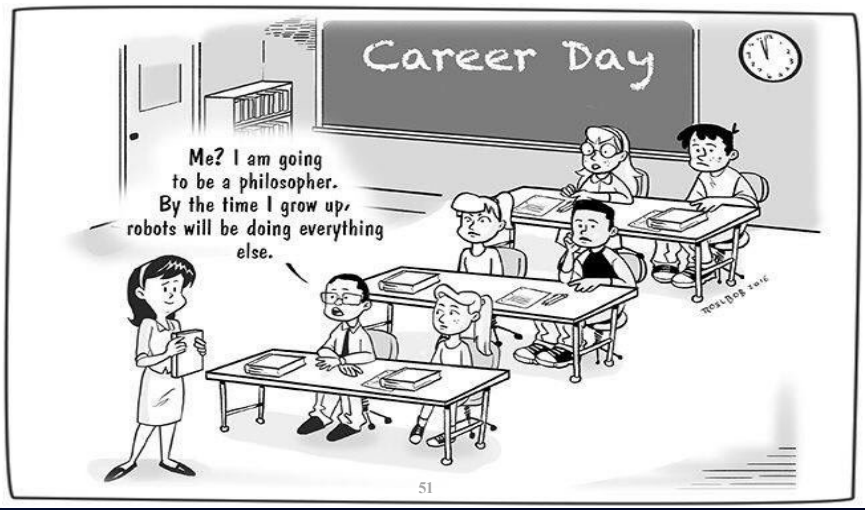
What you will NOT learn!

- You can learn about these on your own by reading manuals (provided you know the fundamentals)
  - For example, any new programming language can be learned in a week
  - Mastery takes longer! See Peter Norvig's excellent article
    - Teach Yourself Programming in Ten Years (http://www.norvig.com/21-days.html)
  - Wise saying : ""A good programmer is someone who always looks both ways before crossing a one-way street."—Doug Linder
    - More at http://www.defprogramming.com/

49

Funny Stuff on Programming Languages

What will you be when you grow up?



51

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)
    - Media (Graphics, Web development, text processing, information retrieval)
    - Telecom (Networking, security)
    - General (System Management)
  - Start-up companies
  - Research Centers (e.g. QCRI, QBRI, QEERI, Google, Microsoft Research, Baidu, Facebook, etc.)
  - Tech Companies (Twitter, Bosch, Salesforce, LinkedIn, Uber, etc.)

52

What will you be when you grow up?

- Graduate Study
  - Master of Science (M. Sc.) (2 years – Advanced Courses + Research+Thesis)
  - Doctor of Philosophy (Ph. D.) (4-6 years – more advanced courses + original research+Thesis)

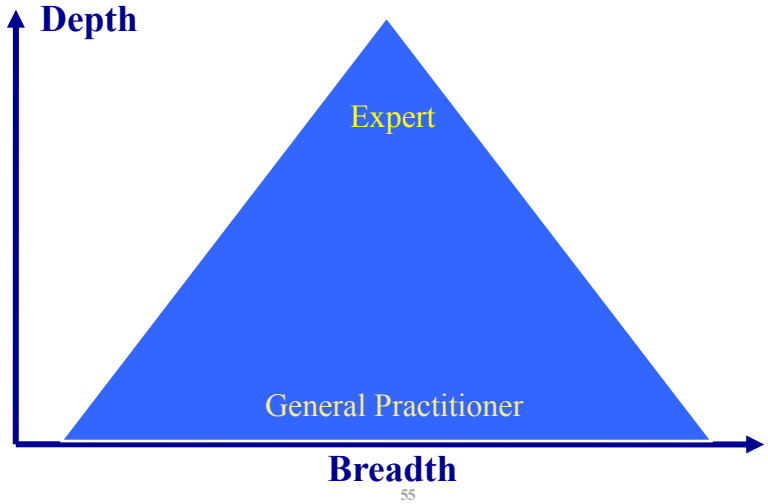
53

What will you be when you grow up?

- Job opportunities
  - Faculty Members/Researchers at Universities
  - Researchers at advanced research labs
  - Research policy managers

54

Specialization



55

Specialization

- An expert is someone
  - who knows more and more

56

Specialization

- An expert is someone
  - who knows more and more
  - about less and less, until

57

Specialization

- An expert is someone
  - who knows more and more
  - about less and less, until
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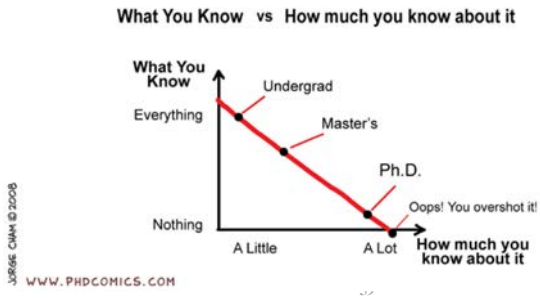
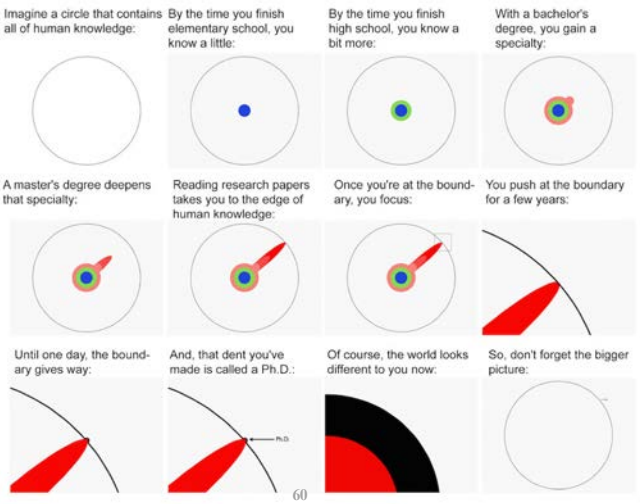
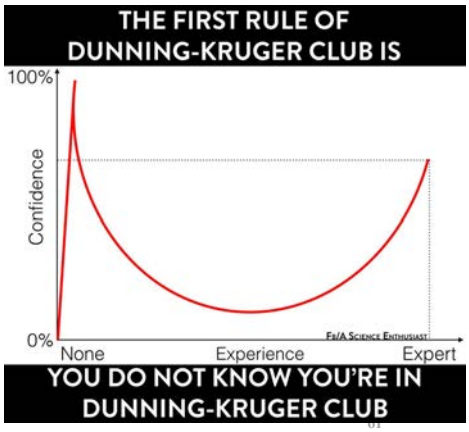


Specialization



Specialization

- Not necessarily a linear process



The Evolution of Computing

- Where are we coming from?

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.

63

The Evolution of Computing

- I suggest all of you watch "2001 A Space Odyssey" (Kubrick 1968) (I am very serious)

to see what the best of minds thought (in 1968) computers would be like in 2001.

- Play Chess
- Dialogue with Humans
- Planning (and Conspiracy)

64

The Evolution of Computing

- 1950's computer

65

The Evolution of Computing

- Then and now!

66

The Evolution of Computing

- 1950's hard disk drive

67

The Evolution of Computing

- 1950's hard disk drive

68

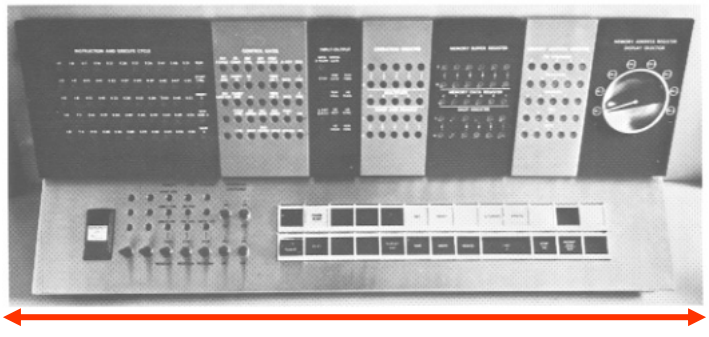
A personal history of computer technology

- 1960's:
  - 100 KHz Machines (IBM 1620),
  - 20-30 KB Memory,
  - Punched Card Input,
  - Teletypes, Line Printers,
  - 10-20 MB Disks
  - Computers consume kilowatts, need serious AC cooling,
  - ARPANET, the precursor to Internet, starts about here also.

69

A personal history of computer technology

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



70

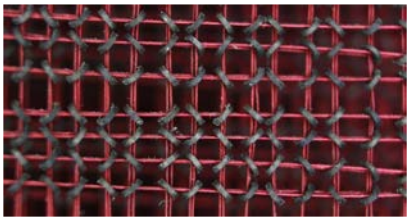
Fortran 2

```
C AREA OF A TRIANGLE WITH A STANDARD SQUARE ROOT FUNCTION
C INPUT - TAPE READER UNIT 5, INTEGER INPUT
C OUTPUT - LINE PRINTER UNIT 6, REAL OUTPUT
C INPUT ERROR DISPLAY ERROR OUTPUT CODE 1 IN JOB CONTROL LISTING
      READ INPUT TAPE 5, 501, IA, IB, IC
  501 FORMAT (3I5)
C IA, IB, AND IC MAY NOT BE NEGATIVE
C FURTHERMORE, THE SUM OF TWO SIDES OF A TRIANGLE
C MUST BE GREATER THAN THE THIRD SIDE, SO WE CHECK FOR THAT, TOO
      IF (IA) 777, 777, 701
  701 IF (IB) 777, 777, 702
  702 IF (IC) 777, 777, 703
  703 IF (IA+IB-IC) 777, 777, 704
  704 IF (IA+IC-IB) 777, 777, 705
  705 IF (IB+IC-IA) 777, 777, 799
  777 STOP 1
C USING HERON'S FORMULA WE CALCULATE THE
C AREA OF THE TRIANGLE
  799 S = FLOATF (IA + IB + IC) / 2.0
      AREA = SQRTF( S * (S - FLOATF(IA)) * (S - FLOATF(IB)) *
     +     (S - FLOATF(IC)))
      WRITE OUTPUT TAPE 6, 601, IA, IB, IC, AREA
  601 FORMAT (4H A= ,I5,5H  B= ,I5,5H  C= ,I5,8H  AREA= ,F10.2,
     +        13H SQUARE UNITS)
      STOP
      END
```

71

A personal history of computer technology

- Magnetic Core Memory (4096 bytes)



72

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73

A personal history of computer technology

- Punched Card Input? What IS that?

74

A personal history of computer technology

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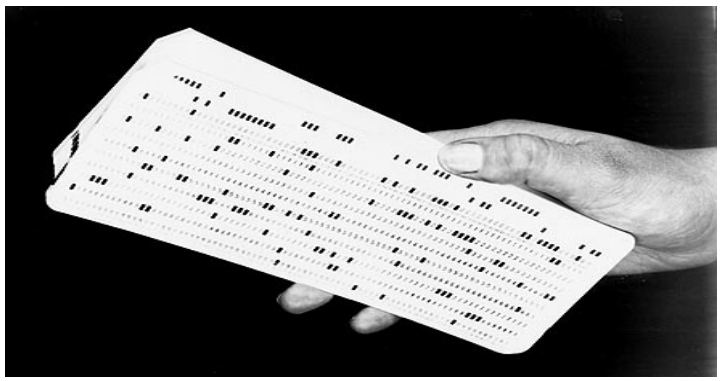

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A personal history of computer technology

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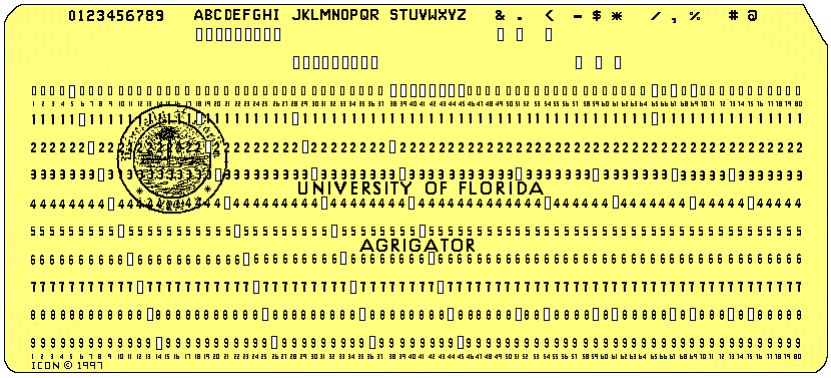


76

A personal history of computer technology

- Input with punch cards

77

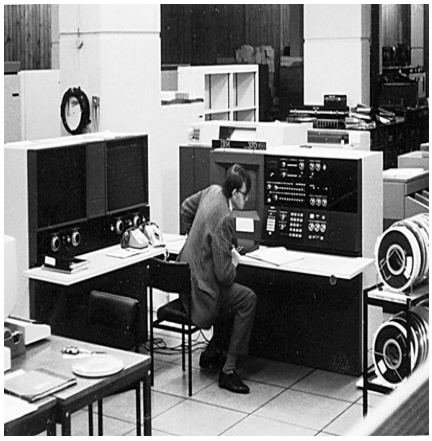
A personal history of computer technology

- Input with punch cards

78

A personal 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

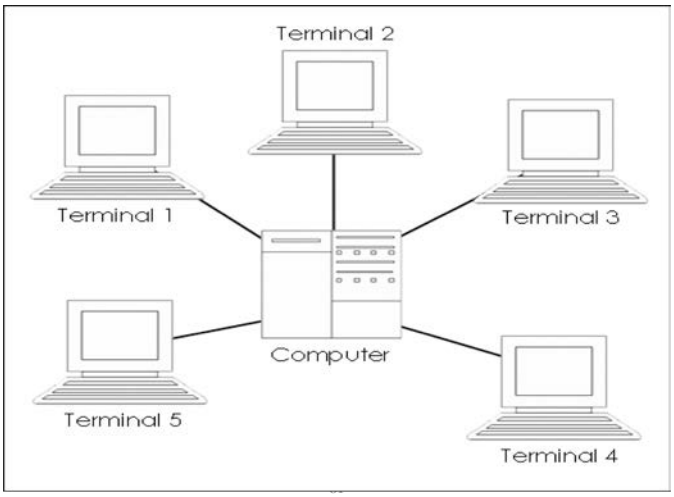


79

A personal history of computer technology

80

Timesharing Computer Systems



A personal history of computer technology

- Late 70's PDP-8
- **4 Kilobytes**, 200 Kilohertz, paper tape

82

A personal history of computer technology

- Late 70's PDP-8

- 4 Kilobytes, 200 Kilohertz, paper tape

83

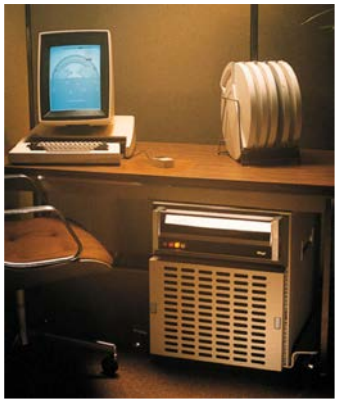
A personal history of computer technology

- 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

84

A personal history of computer technology

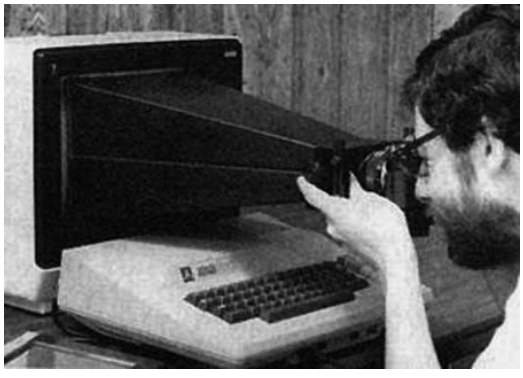
- Mid 80's:
- Xerox Alto Workstation
  - The first real personal computer!
  - Steve Job's is famously rumored to have seen this and then built the Mac.
- 128KB RAM, 5.8 MHz Processor
- Interchangeable 2.5MB personal disk
- Only 2000 units were ever produced.
  - Cost $10,000 1980 dollars to build = $30,614 in 2017 dollars



85

Funny Stuff

- Screen shots then



86

A personal history of computer technology

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

87

A personal history of computer technology

- Late 80's MacIntosh SE
  - 4 MB RAM 40 MB Disk, 20 Mhz
  - 3000 (1988) dollars = 6000 (2014) dollars
  - My first personal computer
- Through 90's,
  - Sun SparcStations
    - 32 MB – 1 GB RAM, 32 – 450 MHz
  - Various Macintoshes
    - 4 MB - 200 MB Ram, 32 – 233 Mhz
  - Various PCs
    - 1 MB – 1GB Ram, 266 – 750 MHz

88

A personal history of computer technology

- 2018
  - Mac Pro, 32G GB Ram, 1TB of SSD Disk
  - 3 GHz 4-core CPU
  - Macbook Pro Laptops (16 G Ram), iPads, iPhone, etc.
- I probably now have significantly more computing power in my room (or in my iPhone) than all of the universities in the Middle East combined had, when I was your age!

89

What is driving all this?

- Semiconductor Technology

90

What is driving all this?

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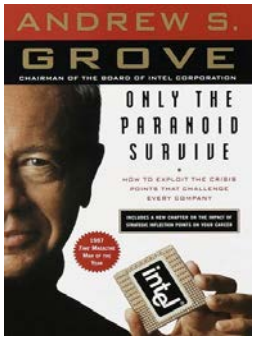
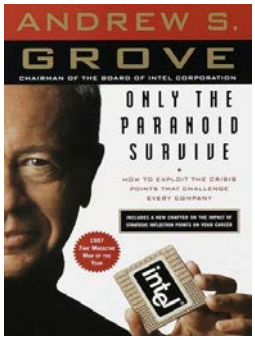


- Paranoia (☺)
  - *Andrew S. Grove (Intel Chairman)*
    - Only the paranoid survive (1996)

91

What is driving all this?

- Semiconductor Technology

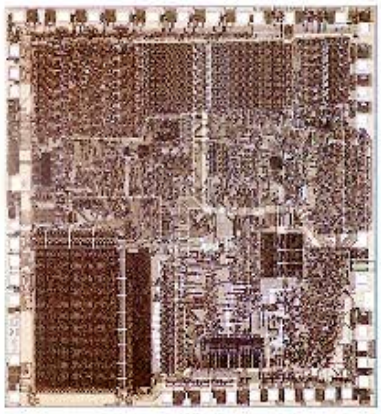


- Paranoia (☺)
  - *Andrew S. Grove (Intel Chairman)*
    - Only the paranoid survive (1996)
- Theoretical breakthroughs
  - It turns out that these have provided the most significant improvement, but we rarely see it mentioned.
    - Average Joe does not understand computational complexity, e.g.

92

Very Large Scale Integrated Circuit Technology

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



93

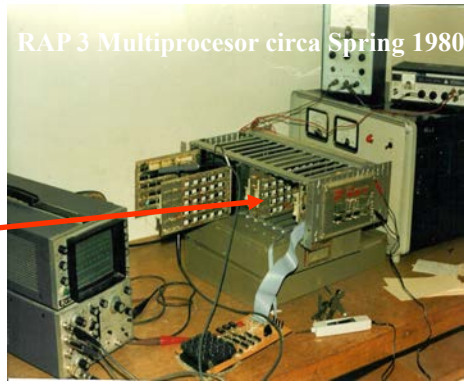
Very Large Scale Integrated Circuit Technology

- 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 Ofiazer

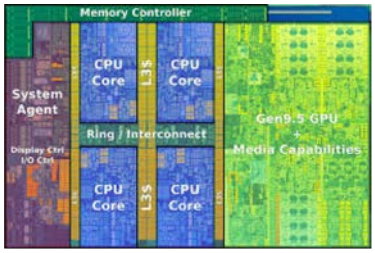
Published in:
- Proceeding
VLDB '78 Proceedings of the fourth international conference on Very Large Data Bases - Volume 4
Pages 300-311



94

Very Large Scale Integrated Circuit Technology

- Intel Coffee Lake– (2017)
  - 4/12-cores + GPU
- ~6 billion transistors
  - 270,000 times that of 8086
- 3.7 Gigahertz
  - ~710 times that of 8086



2011 pins

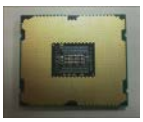
180 Watts

149 mm²

95

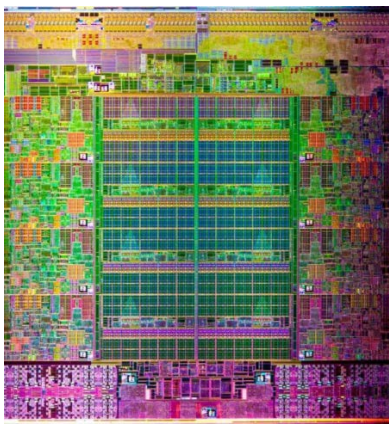
Very Large Scale Integrated Circuit Technology

- Intel Sandy Bridge-E – (2011)
  - 8/16 cores
- 2.27 billion transistors
  - 90,000 times that of 8086
- 3.3 - 3.6 Gigahertz
  - ~700 times that of 8086



2011 pins

180 Watts



435 mm²

96

Very Large Scale Integrated Circuit Technology

	Year	Process	Price	Base / Turbo	Cores / Threads	Socket
Core i7-4790K	2013	22nm	$339	4.0GHz / 4.4GHz	4 / 8	LGA1150
Core i5-4670K	2013	22nm	$242	3.5GHz / 3.9GHz	4 / 4	LGA1150
Core i3-4350	2013	22nm	$138	3.6GHz	2 / 4	LGA1150
Pentium G3220	2013	22nm	$64	3.0GHz	2 / 2	LGA1150
Celeron G1820	2014	22nm	$42	2.7GHz	2 / 2	LGA1150
Core i7-2700K	2011	32nm	$332	3.5GHz / 3.9GHz	4 / 8	LGA1155
Core i5-2500K	2011	32nm	$216	3.3GHz / 3.7GHz	4 / 4	LGA1155
Core i7-870	2009	45nm	$562	2.93GHz / 3.6GHz	4 / 8	LGA1156
Core i5-760	2009	45nm	$205	2.8GHz / 3.33GHz	4 / 4	LGA1156
Core 2 Quad Q9650	2008	45nm	$530	3.0GHz	4 / 4	LGA775
Core 2 Quad Q6600	2007	65nm	$530	2.4GHz	4 / 4	LGA775
Core 2 Duo E8600	2008	45nm	$266	3.33GHz	2 / 2	LGA775
Core 2 Duo E6600	2006	65nm	$316	2.4GHz	2 / 2	LGA775

Can you spot some trends here?

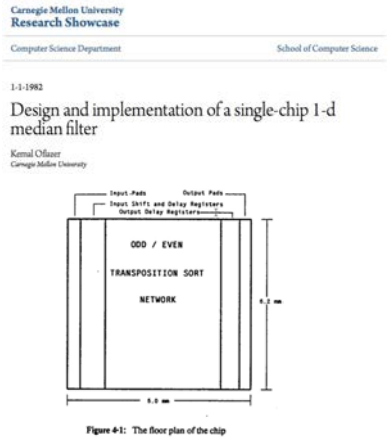
Reality Check

- Physics says $Power = CV^2 f$
- C is capacitance
- V is voltage
- f is chip clock frequency
- Intel Core I7-4790 processor consumes 88 Watts
- One needs to be very careful for mobile platforms!
  - New chips for mobile
  - Intel Skywell (2016) will run at 15Watts

98

Very Large Scale Integrated Circuit Technology

- CMU in the 1980's was a hotbed of VLSI chip design research
- Undergraduate and Graduate Courses on VLSI chip design
- Design – Send by Email – Get 100 copies of your chip in the mail - Test



Carnegie Mellon University
Research Showcase

Computer Science Department | School of Computer Science

1-1-1982

Design and implementation of a single-chip 1-d median filter

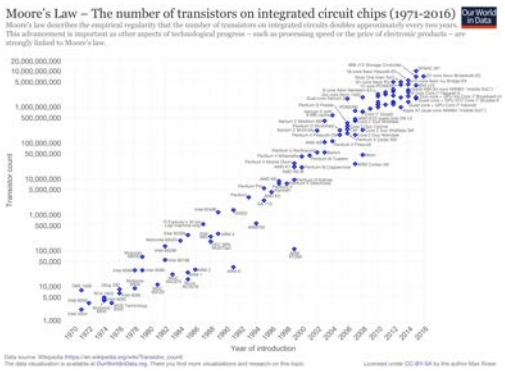
Kemal Ofiazer
Carnegie Mellon University

Figure 4-1: The floor plan of the chip

99

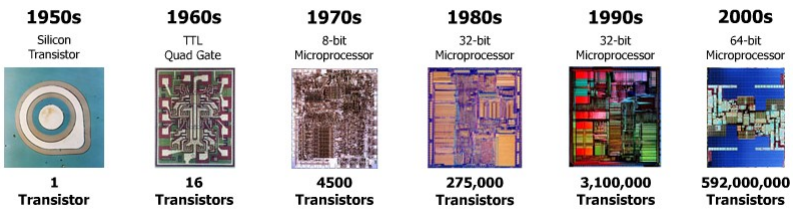
Very Large Scale Integrated Circuit Technology

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



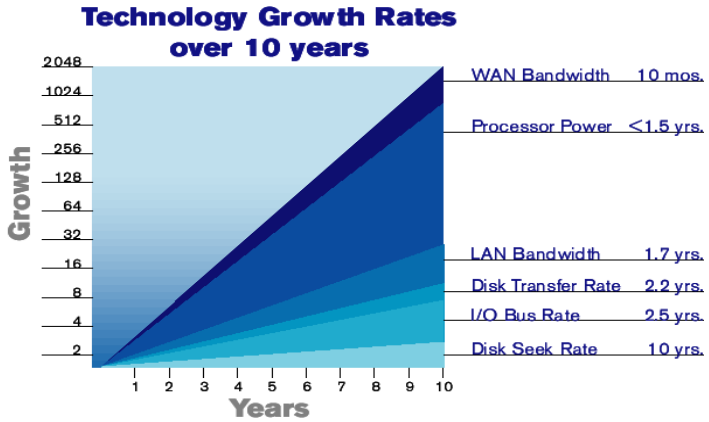
100

Moore's Law



101

Other trends



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

102

Other trends

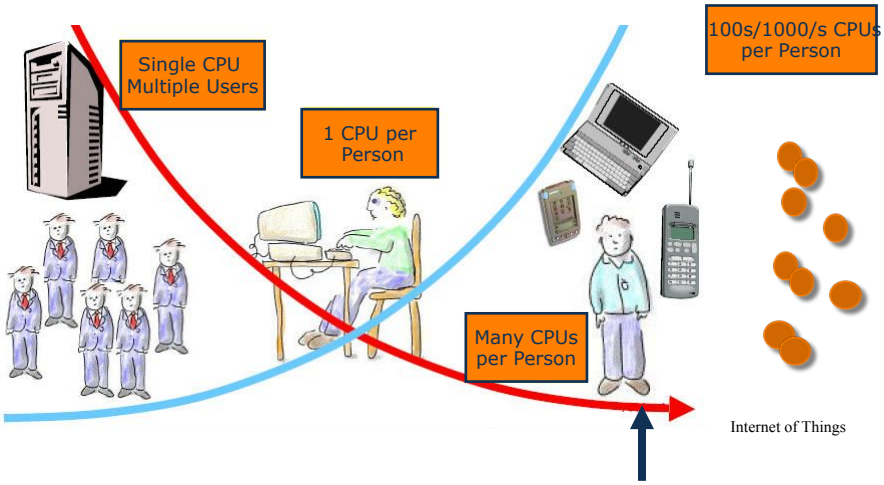
Average Cost of Hard Drive Storage

Year	Average Cost Per Gigabyte
2016	$0.019
2015	$0.022
2014	$0.03
2013	$0.05
2010	$0.09
2005	$1.24
2000	$11.00
1995	$1,120
1990	$11,200
1985	$105,000
1980	$437,500

Exponential Growth

- It is good when it applies technological advance
- 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 available.
    - Universe has been around for about $15 * 10^9$ years!
  - Wait for Prof. Kapoutsis to explain you that!

Where we are heading?



105

Where are we now?

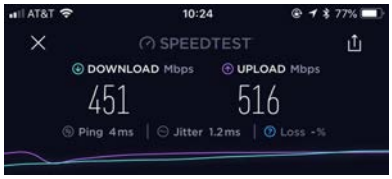
- Late 2010's:
  - Wireless networks are pervasive(3/4/5G, IEEE 802.11, Bluetooth)
  - Broadband reaches households
    - Some countries have 100Mb/1GB line to homes
  - Mobile computing
  - Convergence of hand-held devices (telephone, PDA, Mp3 player, radio, camera, watch)
  - Convergence of home information and entertainment appliances (PC, TV, DVD & CD players)
  - Smart Homes
  - Computing in the "cloud"
  - Deep Learning and AI

106

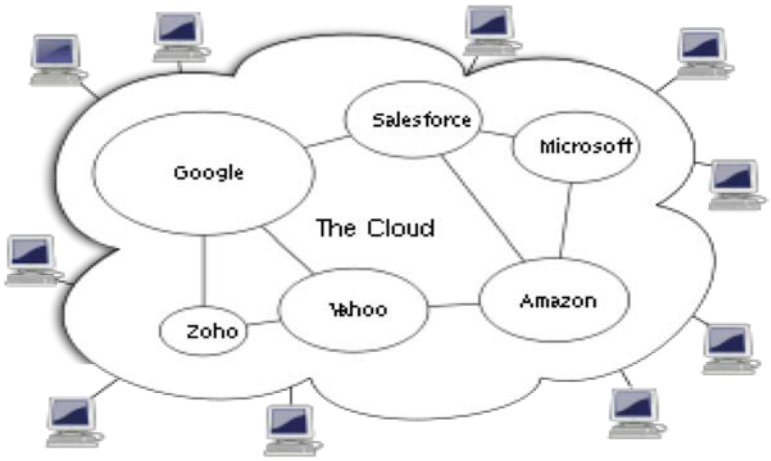
Broadband Speed

- World Average is about 7.1 Mbit/s

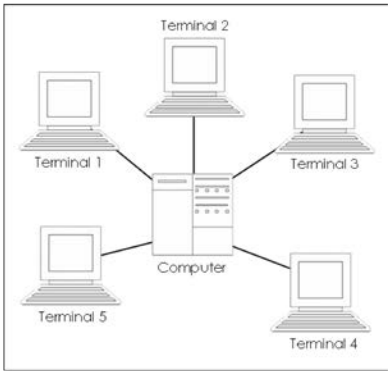
Ranking position	Country	Mean Download Speed
1	Singapore	60.39
2	Sweden	46.00
3	Denmark	43.99
4	Norway	40.12
5	Romania	38.60
6	Belgium	36.71
7	Netherlands	35.96
8	Luxembourg	35.34
9	Hungary	34.01
10	Jersey	30.90
11	Switzerland	29.92
12	Japan	28.94
13	Latvia	28.63
14	Taiwan	28.09
15	Estonia	27.91
16	Spain	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

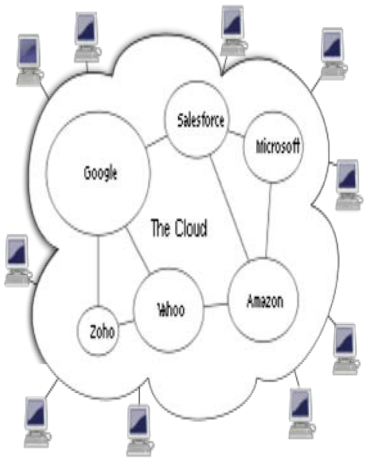


Cloud Computing



Cloud Computing





1970's

2010's

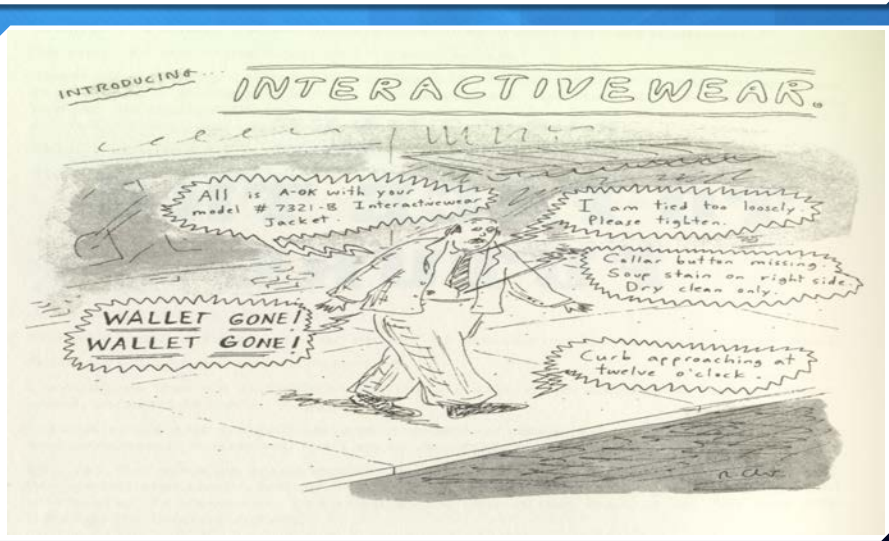
109

Happening Now

- Late 2010s:
  - Cars, appliances, telephones, everything have some computing power somewhere,
  - Essentially infinite bandwidth (and wireless too),
  - Speech and visual interfaces, slowly coming
    - Siri, Kinect, Google Now, Alexa
  - Wearable computers
    - Google Glass (?)
    - Smart Watches
    - Virtual Reality
  - Trackers
    - Fitbit, Apple Watch, Smart Implants

110

Fun Stuff -- Wearable Computers



The Century 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
- What we do with all this computing power?
- What would we do with all this memory?
  - Suppose you could "remember" everything you see, hear, touch, smell

Some grand challenges in computing

- Modelling and fast simulation of living biological structures
  - Cells, Brain, Organs
- Practical ubiquitous computing
  - Computers everywhere but hidden
- Capture and access 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 is the new math!)

113

Artificial Intelligence

- Here is a challenge

Artificial Intelligence

- Here is a challenge
- Can you build a computer that would watch this clip and laugh?
- Computational Humor!

Short Term Trends

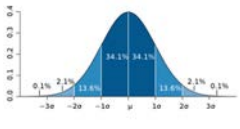
- Machine Learning/Deep Learning/AI
- Robotics
- Watson-like applications in many domains
- Autonomous Driving

Short Term Trends

117

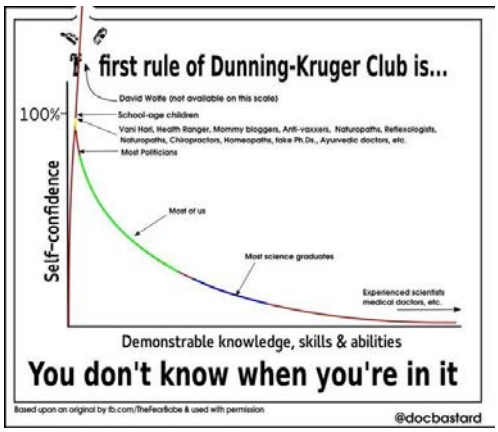
Final Words and Advice

- You will be living in a "bubble" for at least the next 4 years
  - Interacting with smart, hardworking 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
- Learn about the normal distribution



118

Dunning-Kruger Club



119

So

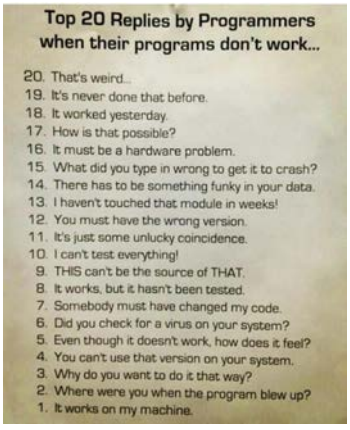
120

Final Words and Advice

- Develop a healthy appreciation of Humor
  - Especially Computer Humor – Seriously!
    - Most of it is self-deprecating
  - Here are some examples
  - If you do not get any of these – you will, in due time

121

Computer Humor



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

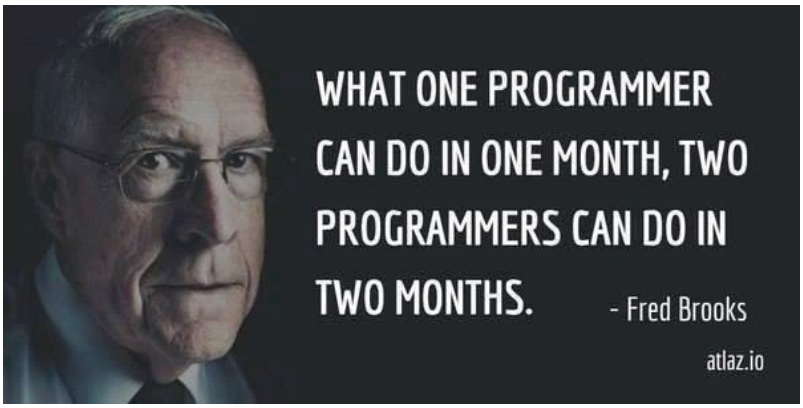
20. That's weird...
19. It's never done that before.
18. It worked yesterday.
17. How is that possible?
16. It must be a hardware problem.
15. What did you type in wrong to get it to crash?
14. There has to be something funky in your data.
13. I haven't touched that module in weeks!
12. You must have 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.

122

Computer Humor

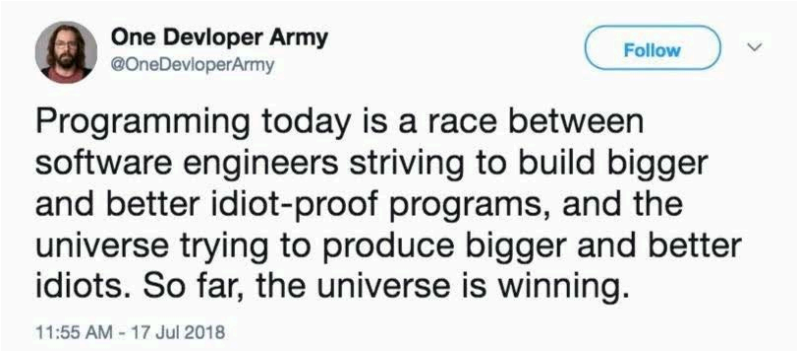
123

Computer Humor



124

Computer Humor



125

Computer Humor

126

Computer Humor

Computer Humor

```java
public static boolean isEqual(int a, int b) {
    try {
        int c = 1 / (a - b);
    } catch (ArithmeticException e) {
        return true;
    }
    return false;
}
```

Don't ever do something like this!

Computer Humor

129