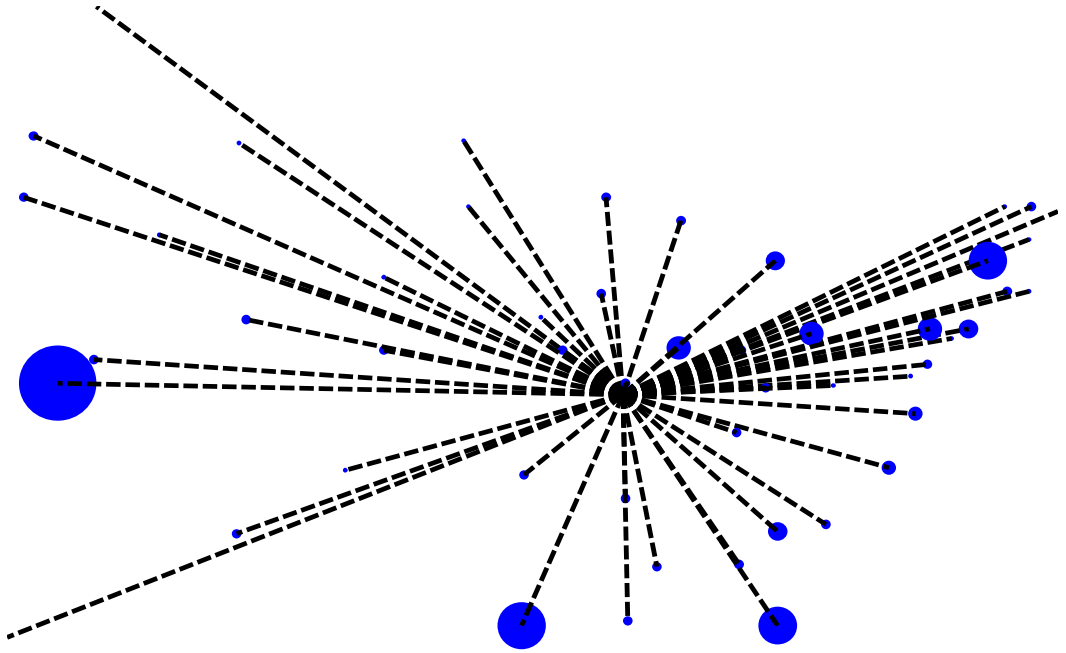
From Boole to Google and Back

Do The Math! (Chapter 7: Counting and Computers)

John K. White



http://www.sagepub.com/books/Book236964

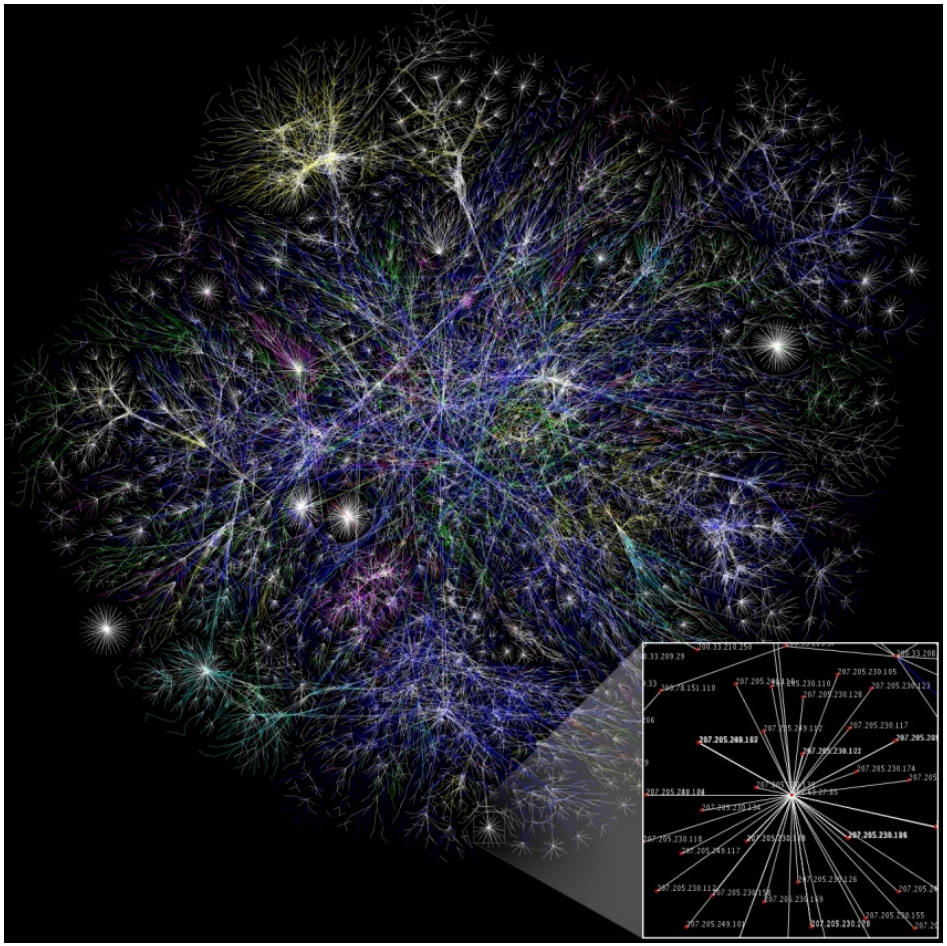
http://www.johnkwhite.ie/

1. **A short history of computing**
2. **How does a computer work**
3. **The language of a computer**
4. **Some computer applications**

Along the way,

- Abacus and ENIAC
- George Boole and Westlife
- Sputnik and the PC
- US Census and IBM
- BASIC, HTML, Excel, . . .
- Rockets, probability, Monopoly, poker, . . .

To err is human.
To completely foul things up . . .

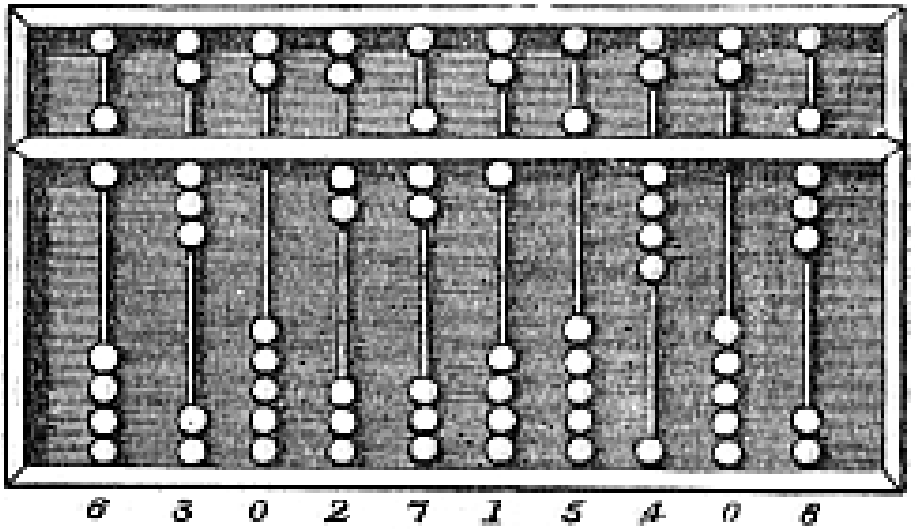


takes a computer

1. A short history: Abacus to ENIAC

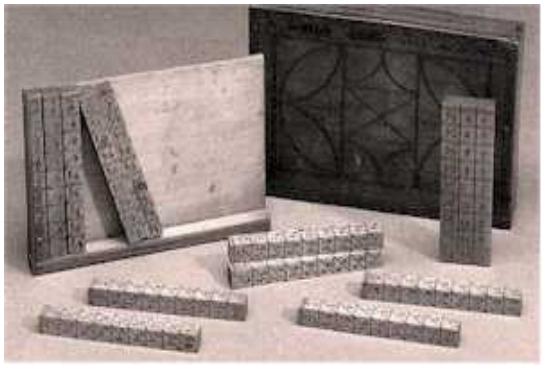
600 BC

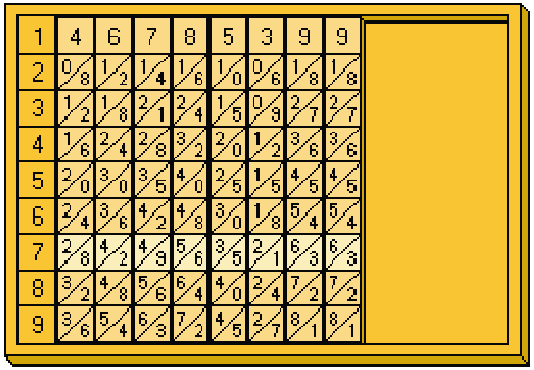
Chinese abacus

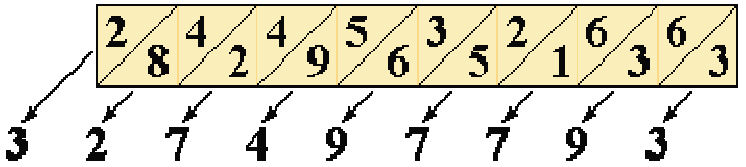


- Add, subtract, multiply, divide, take the square root.
- From the Greek *abax* for “calculating board.”
- *Suan pan* in Mandarin, meaning “calculating plate.”
- The first “**computer.**”

1617
Napier's Bones







- Set of rods marked at the top with a counting number.
- Multiply by adding diagonally from right to left along a row (e.g., 46785399 x 7).
- Form of **logarithm** (exponents add when multiplied).
- Aided astronomical calculations of Tycho Brahe and Johannes Kepler.
- The precursor to the modern slide rule.

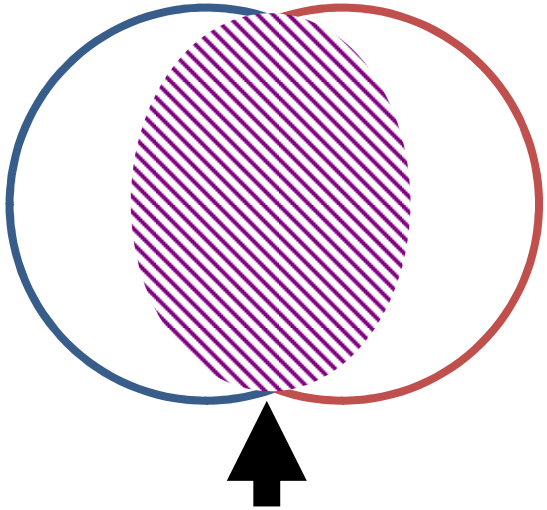
1801

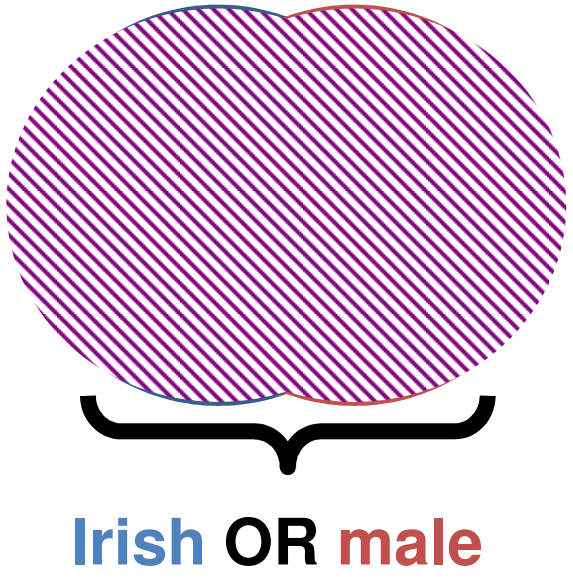
Jacquard loom

- The Jacquard loom controlled the weaving with pattern-encoded **punch cards**. A hole determined the loom action.
- Only very simple patterns were woven with the mass-production fabric-making machines of the Industrial Revolution.
- Up to 10,000 cards made up a "**program**."

1851

George Boole (and Boolean logic)





- **Logic** as simple **algebra**: AND and OR (and NAND, NOR).
- A AND B is the intersection (e.g., # of Irish males) (restricts).
- A OR B is the union (e.g., # of Irish or male) (expands).
- Truth tables, binary logic, search parameters.

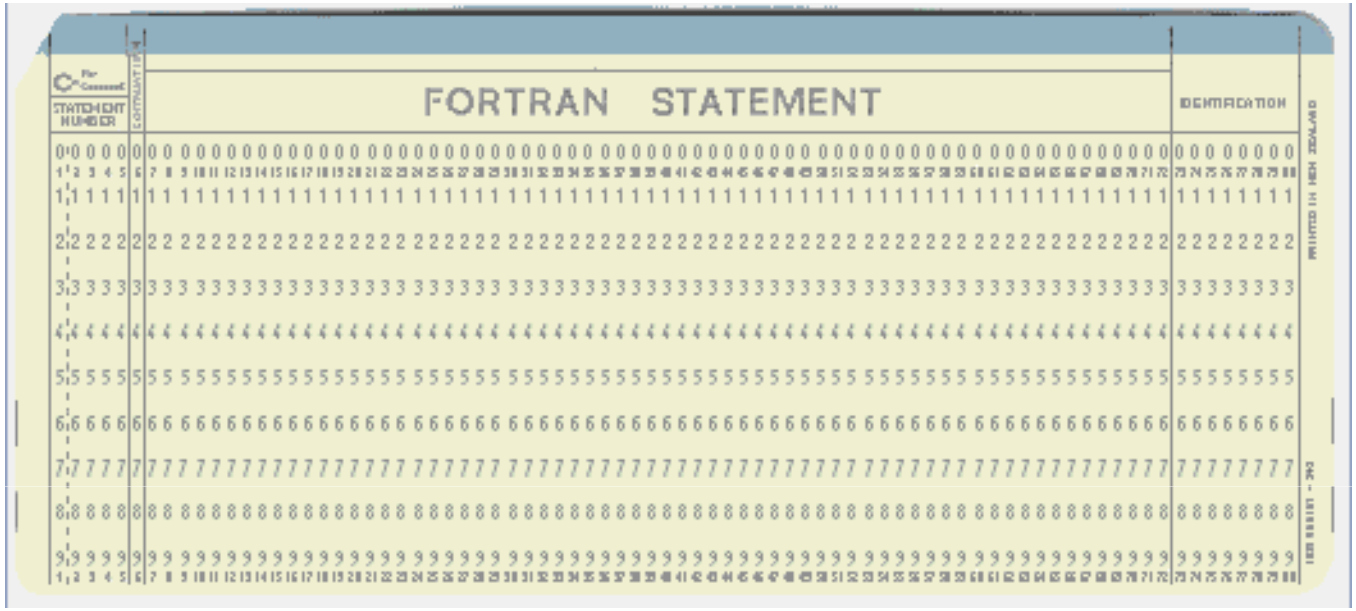
2012

Search engines

- Google, Yahoo!, Bing, Ask Jeeves, AOL Search, ... (Top 5 = 99%).
- Boolean logic to restrict (A AND B) or expand (A OR B) hits.
- A AND B, A OR B, A AND NOT B.

Westlife	35,200,000
McFadden	21,900,000
Westlife OR McFadden	74,900,000
Westlife AND McFadden	999,000
Westlife + McFadden	999,000
“Brian McFadden” + “Delta Goodrem”	641,000

1890
Herman Hollerith

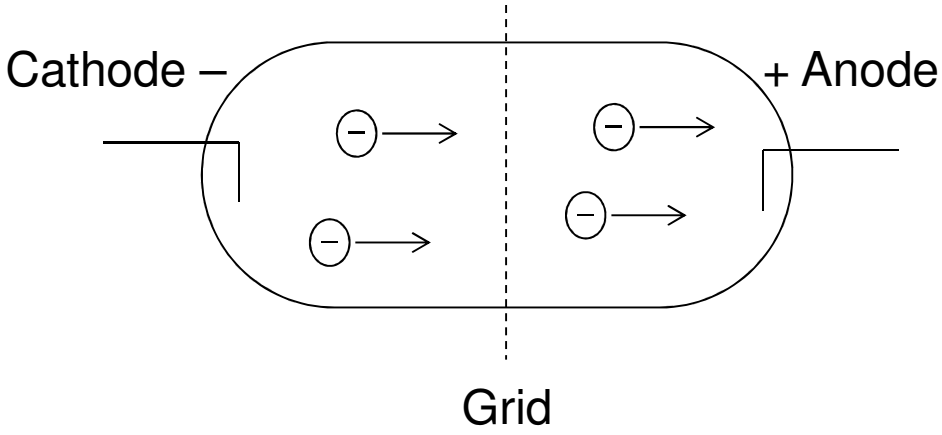


IBM

- Paper medium for inputting data.
- The **punched card** was first used by the New York City Board of Health and several states for statistics tabulation.
- Punched cards were then used in the **1890 U.S. Census** by the Tabulating Machine Corporation (soon to be IBM).

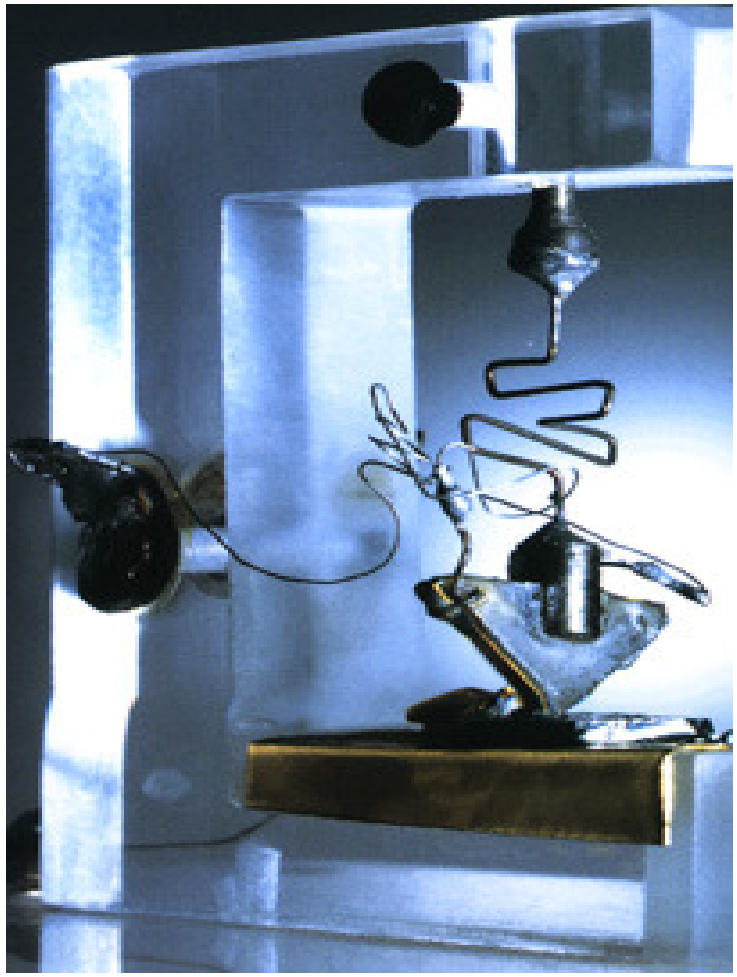
1912

Triode vacuum tube



- **Lee De Forest** added a third electrode (or grid consisting of small wires surrounding the cathode) to the vacuum tube.
- The grid's negative potential controlled the flow of electrons from the cathode to the anode.
- The lower the potential, the more electrons could flow, thus producing an **amplified current**.

1947
Point contact transistor



Bell Labs

The point contact transistor (**transfer resistor**) was invented at Bell Labs by Shockley, Bardeen, and Brattain. ("This thing must have gain.")

Base so-called because the germanium semiconductor rested on the "base." (**Collector** and **emitter** are vacuum tube terms.)

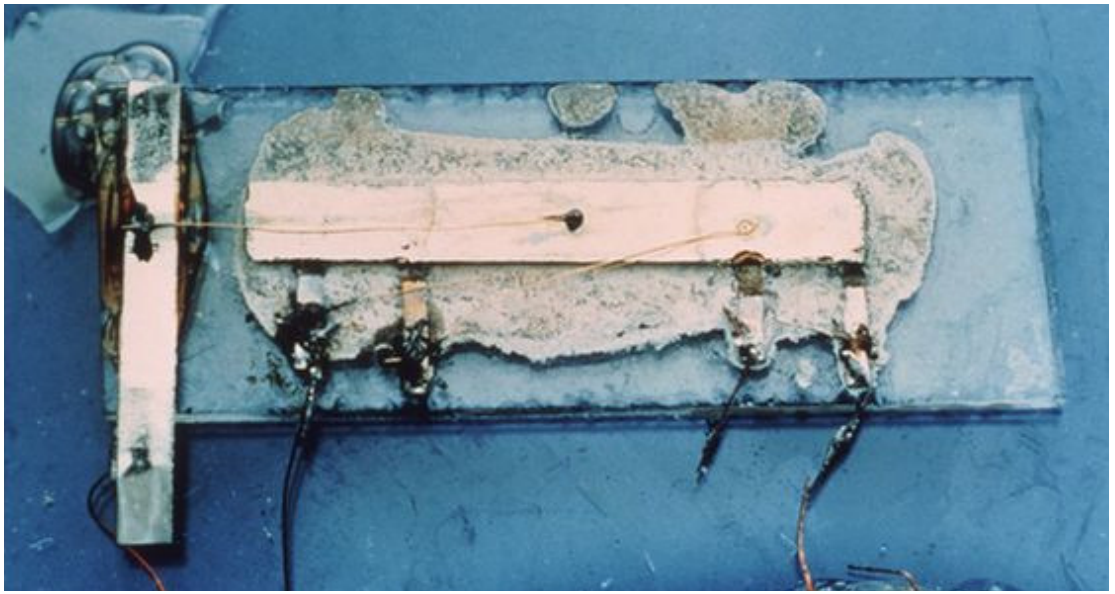
Amplified a current as in a vacuum tube (but not prone to breakdowns).

The junction transistor was invented a year later.

Silicon eventually replaced germanium.

1958

Integrated circuit (IC or chip)

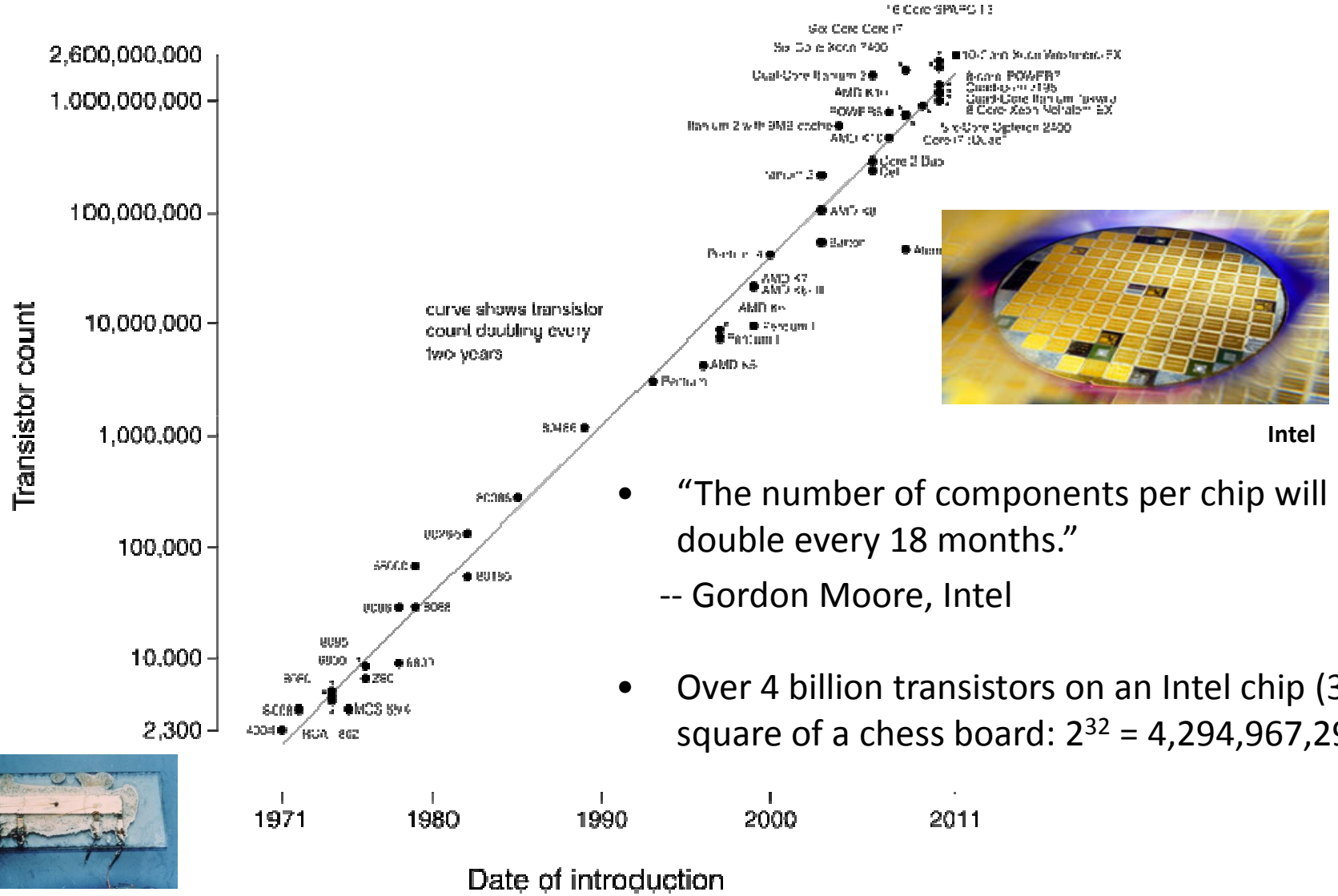


Texas Instruments

- Cutting individual transistors, attaching electrodes, and reconnecting was difficult.
- Jack Kilby (**Texas Instruments**) and Bob Noyce (**Intel**) both had the idea of “wiring” a circuit on one piece of semiconductor.
- The first integrated circuit (IC) consisted of one transistor, one resistor, and one capacitor on germanium. Silicon was used soon after.

1964

Moore's Law



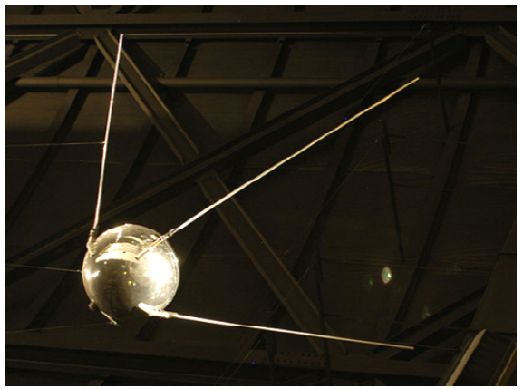
Intel

- "The number of components per chip will double every 18 months."

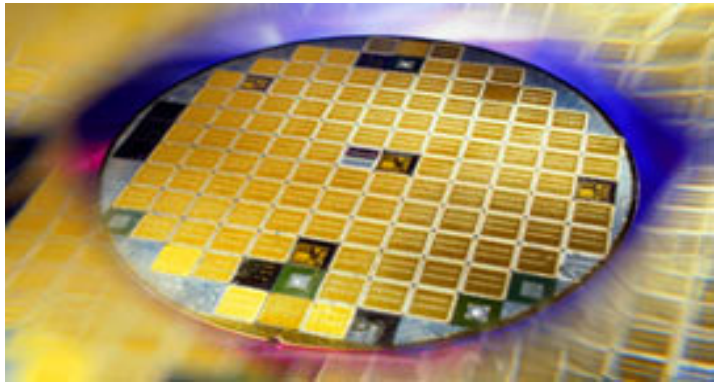
  -- Gordon Moore, Intel

- Over 4 billion transistors on an Intel chip (32nd square of a chess board: 2^{32} = 4,294,967,296).

1957-1969-1971
Sputnik-Apollo-Intel



NASA

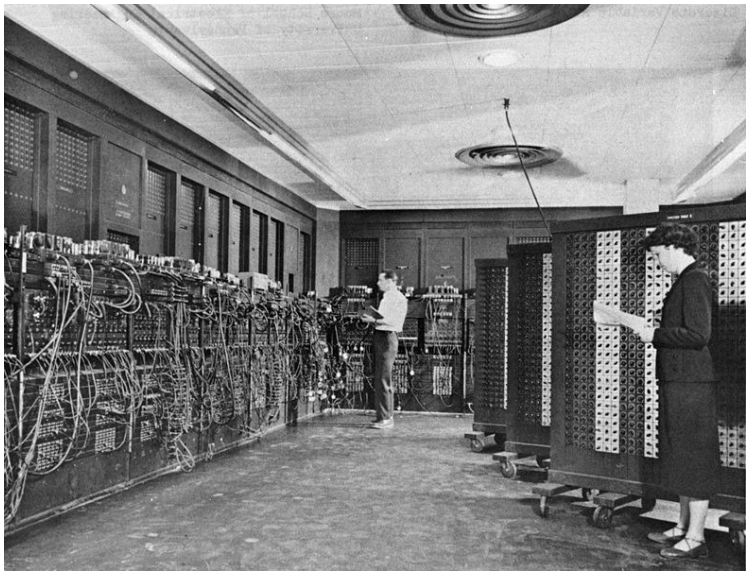


Intel

- The USSR launched **Sputnik** (meaning satellite) . . . and the space race had begun.
- The first artificial satellite was the **size of a basketball**, weighed 183 pounds, and took 98 minutes to orbit the earth. After 57 days in orbit, it was destroyed during re-entry to the atmosphere.
- "Never before had so small and so harmless an object created such consternation." Daniel J. Boorstin, *The Americans: The Democratic Experience.*
- Sputnik and the following Russian and American space programs (with help from Intel) lead to miniaturized and cheaper computer components. **SPUTNIK** **APOLLO**

ENIAC

World War II code breaking



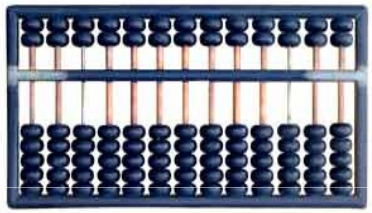
University of Pennsylvania

1946 ENIAC: University of Pennsylvania (ballistic trajectories), 100,000 components, 18,000 tubes. Each valve - 4 months, 1 every 10 minutes. 100 x 10 x 3 feet, 3 tons.

1968 Apollo 8: First trip to the moon. 3000 times smaller than ENIAC.

MARVIN

Abacus to ENIAC
to the €200 netbook



600 BC

add
subtract
multiply
divide
square root

1946

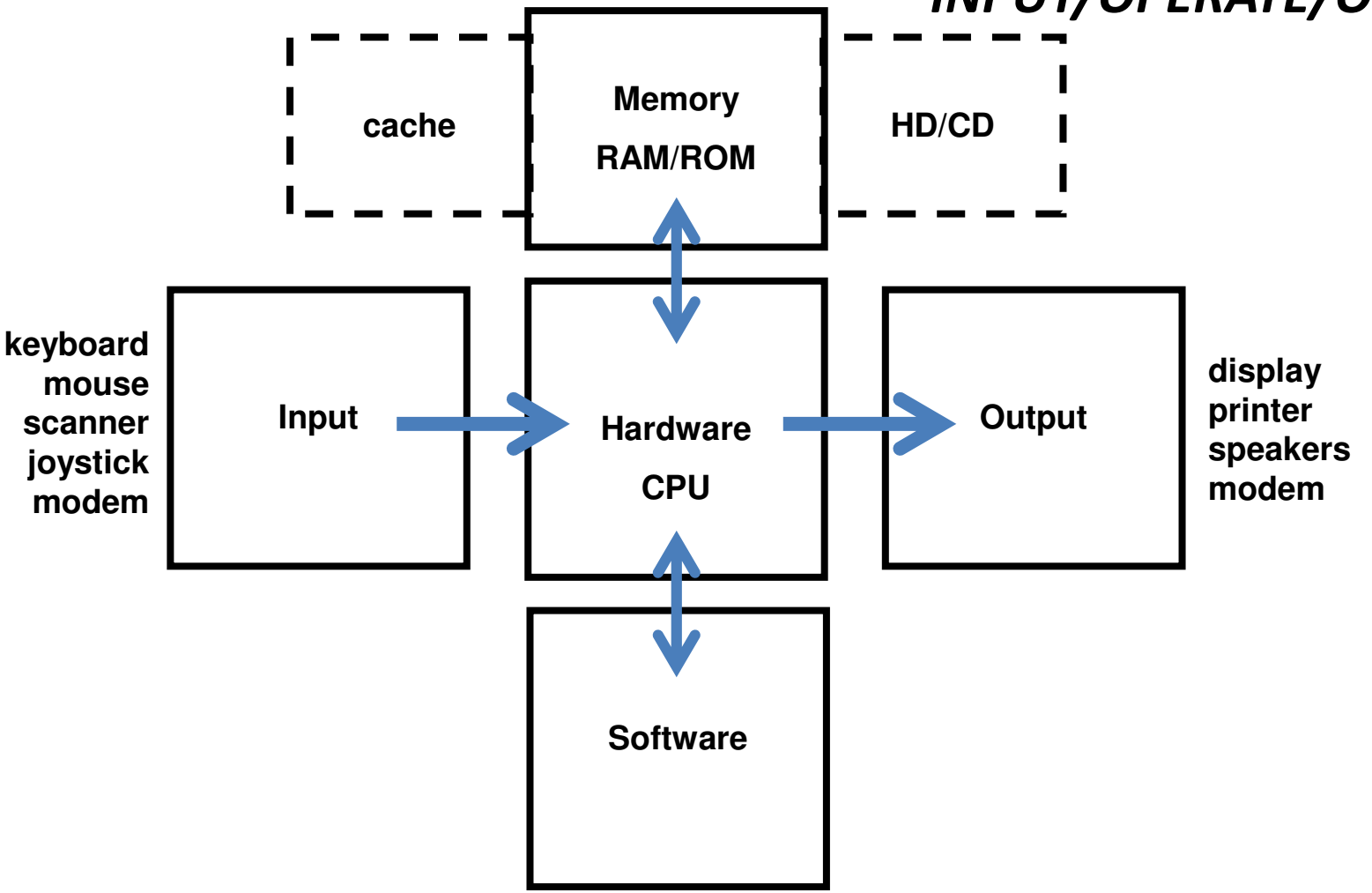
5,000 additions/
subtractions per minute
ballistic trajectories
atom bomb calculations

2012

dual core chips
2 GB RAM
1.5 GHZ clock
250 GB hard drive

Configuration

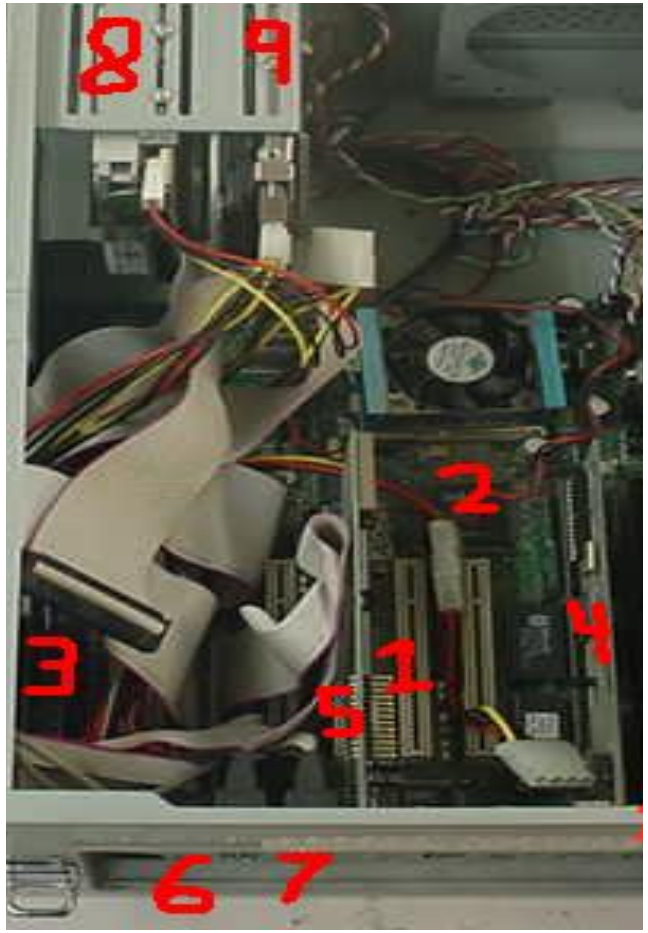
INPUT/OPERATE/OUTPUT



memory/input/output connected by data buses 8-bit/16-bit/32-bit

stand-alone or networked (LAN/WAN)

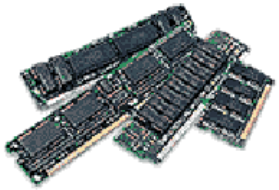
1. Motherboard
2. CPU
3. RAM
4. NIC
5. Video card
6. Com ports
7. Parallel line port
8. Floppy disk drive
9. Hard disk drive



1

2

3



Hardware is hard --
can crush your fingers

Data

Bits and bytes

Computers speak in "binary," the first language of a computer

What is a bit (binary digit)?

- **the smallest amount of data**
- **has two states: binary (0 or 1)**
- **perfect for binary arithmetic (base 2)**
- **powers of 2: $2^3 = 8$**
- **8 bits = 1 byte**

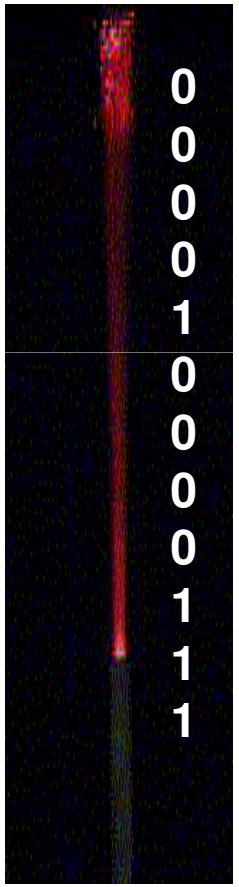
binary numbers (1-8)

0000 = 0
0001 = 1
0010 = 2
0011 = 3
0100 = 4
0101 = 5
0110 = 6
0111 = 7
1000 = 8

$0000 = 0x2^3 + 0x2^2 + 0x2^1 + 0x2^0$
$= 0x8 + 0x4 + 0x2 + 0x1$
$= 0$

$0111 = 0x2^3 + 1x2^2 + 1x2^1 + 1x2^0$
$= 0x8 + 1x4 + 1x2 + 1x1$
$= 7$

$1000 = 1x2^3 + 0x2^2 + 0x2^1 + 0x2^0$
$= 1x8 + 0x4 + 0x2 + 0x1$
$= 8$



000010000111

Serial or parallel

'087' = W (ASCII)

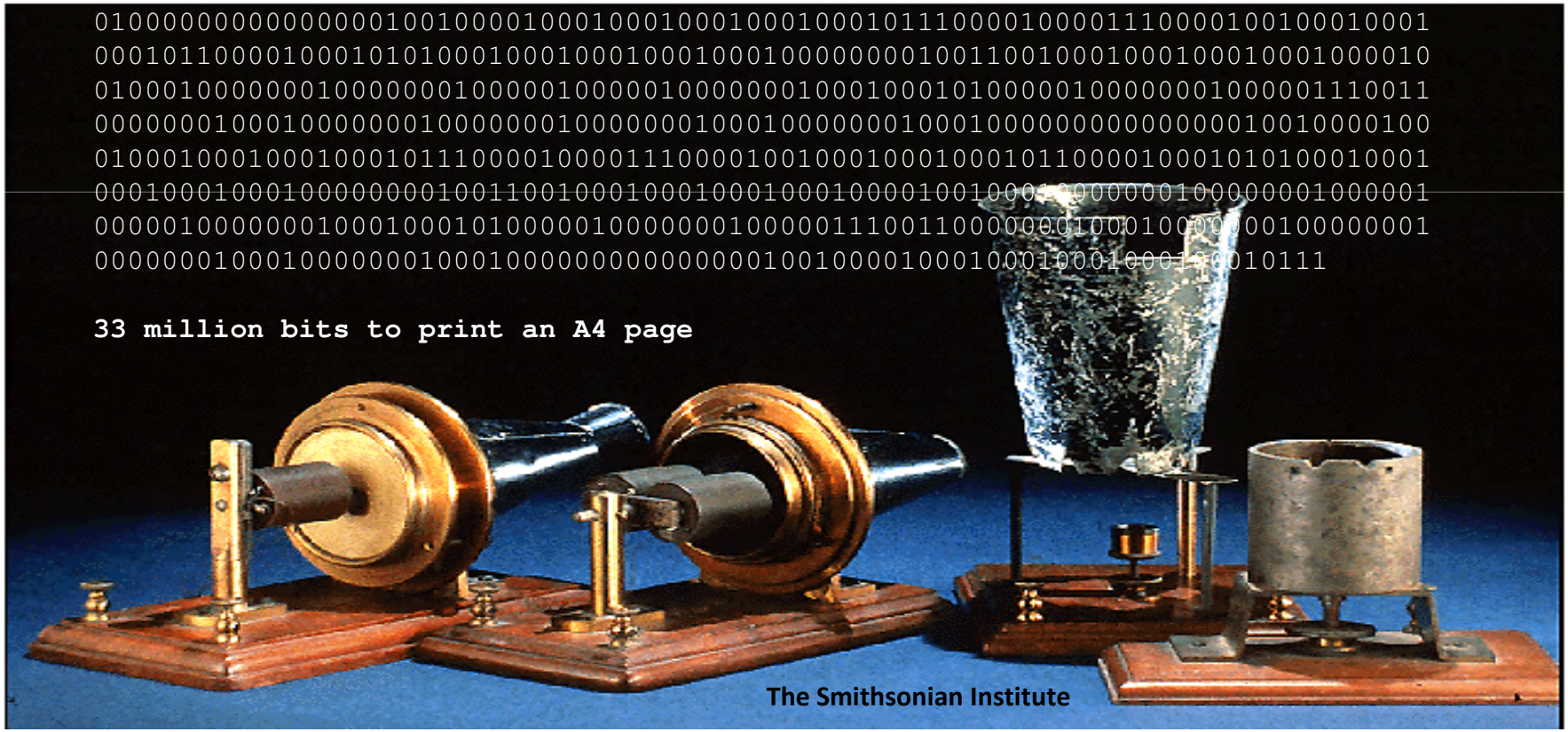
Data transmission

Bits and bytes

First electronic speech in 1876 (by Alexander Graham Bell and Thomas Watson)

"Watson come here I need you“ (312 bits or 39 bytes)

Made from a wooden stand, funnel, cup of acid, and some copper wire



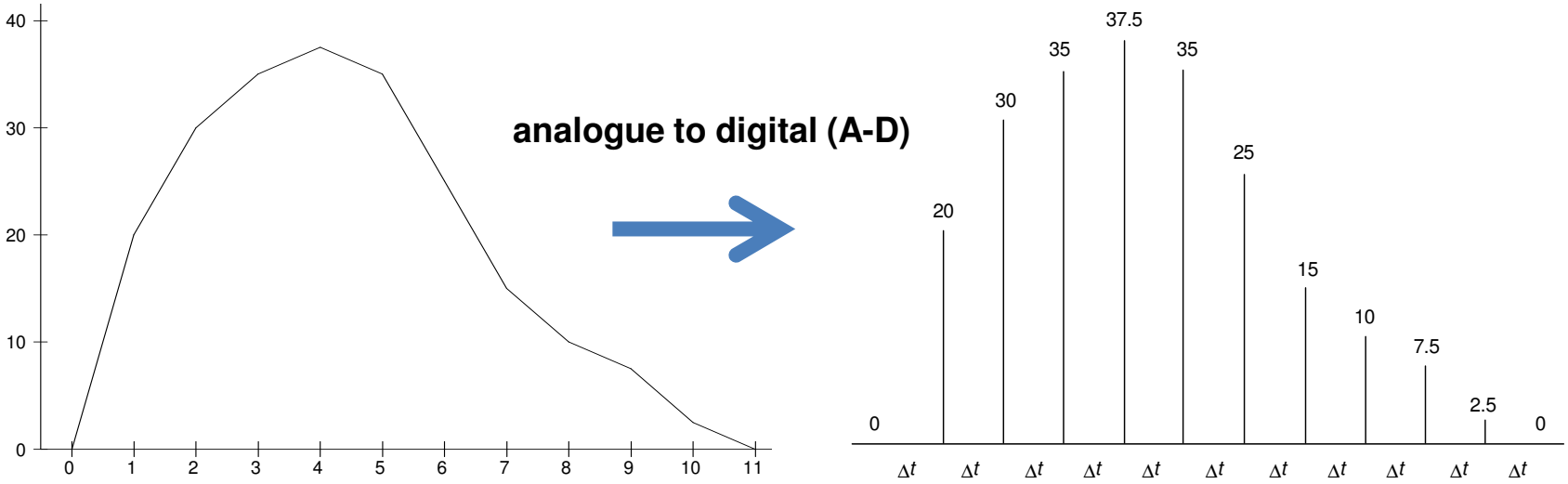
Data transmission

Analogue and digital

Any physical measurement is an analogue (sound, temperature, . . .)

Measurements are converted from analogue to digital

The amount of "sampling" or number of points = the resolution



Sample frequency → resolution/size. The greater frequency, the better reproduction but bigger the file.

1 k	**10^3**	**1 "kay"**	**1,000**
1 M	**10^6**	**1 "Meg"**	**1,000,000**
1 G	**10^9**	**1 "Gig"**	**1,000,000,000**
1 T	**10^{12}**	**1 "Tera"**	**1,000,000,000,000**

Compare a "googleplex" (so-called largest number)
google = 10^{100} (followed by 101 zeros), googleplex = $10^{\text{googleth}} \approx \infty$

Software

Programming the recipe

February 3, 1976

Assembly
APL
BASIC
C
C++
COBOL
FORTRAN
HTML
Java
JavaScript
Visual Basic
Visual C
…

To me, the most critical thing […] is the lack of good software …. Without good software […], a hobby computer is wasted. Will quality software be written […]?

Almost a year ago, [we] developed Altair BASIC. Though the initial work took only two months, [we] have spent most of the last year documenting, improving and adding features to BASIC. Now we have 4K, 8K, EXTENDED, ROM and DISK BASIC. The value of the computer time we have used exceeds $40,000.

… I would appreciate letters from any one who wants to pay up, or has a suggestion or comment.

William H Gates III

BASIC I

Math equation = computer statement

The first principle of every program

input

↓

operate

↓

output

```
10 X = 3
20 Y = X^2
30 PRINT Y

9
```

Any equation can be “coded”

EQUATE

BASIC II

Repeated calculations = a loop

Any equation: square, cube, general polynomial

input

↓

operate

↓

output

```
10 FOR X = 1 TO 10
20    Y1 = X^2
30    Y2 = X^3
40    Y3 = 2*X^2 + 3*X + 6
50    PRINT Y1, Y2, Y3
60 NEXT X
```

1	1	11
4	8	20
9	27	33
16	64	50
25	125	71
36	216	96
49	343	125
64	512	158
81	729	195
100	1000	236

POLY

BASIC III

The average and st. dev. of 10 numbers

input

↓

operate

↓

output

```
N = 10
DATA 9,4,7,6,8,4,9,7,8,8
FOR I = 1 to N
   READ NUMBERS(I)
NEXT I
SUM = 0: SSQ = 0: AVERAGE = 0: SD = 0
FOR I = 1 to N
   SUM = SUM + NUMBERS(I)
NEXT I
FOR I = 1 to N
   SSQ = SSQ + (NUMBERS(I) - SUM/N)^2
NEXT I
AVERAGE = SUM/N
SD = SQR(SSQ/(N-1))
PRINT "Ave. = " AVERAGE, "Stn. dev. = " SD


Ave. = 7     Stn. dev. = 1.825742
Ok
```

INPUT: 10 numbers (*e.g.*, test marks). *What goes in.*
OPERATE: The guts of a program. The code.
OUPUT: Printout. *What goes out.*

STAT

HTML I

The famous "Hello World" ap

Hypertext markup language (HTML)

- Visual browser (Explorer, Firefox, Chrome, Safari, Opera, Android, . . .)
- What you see is not what you get (cf. WYSIWYG)
- Nested tags (open and close) e.g., <head></head> and <body></body>

```
<HTML>
  <head>
    <title>
      My first web page
    </title>
  </head>
  <body>
    <h1>Hello world</h1>
  </body>
</HTML>
```

FIRST

HTML II

Some of the bells and whistles

Hypertext markup language (HTML)

- Lots of markups <tag></tag>
- View source of any web page (right click)
- Cut and paste to save text, right-click to save images
- Non-linear *hypertext*

```
<HTML>
<head>
        <title>My second web page </title>
</head>
<body bgcolor="00FFFF">
        <h1>Heading 1</h1>
        <h2>Heading 2</h2>
        <h3>Heading 3</h3>
        Some text<br>
        More text<p>
        <b>bold</b> text in <i>italics</i>
        <li> list 1 </li>
        <li> list 2 </li>
        <li> list 3 </li>
        <hr>
        <img src = “Sputnik.jpg” align=top width=150
        height=150 border=0></a>
        <img src = “Apollo.jpg” align=top width=150
        height=150 border=0></a>
        <img src = “Marvin.jpg” align=top width=150
        height=150 border=0></a>
        <a href = “First.html">go to link</a><br>
</body>
</HTML>
```

SECOND

1 number crunching

Coding equations and other Monte Carlo simulations

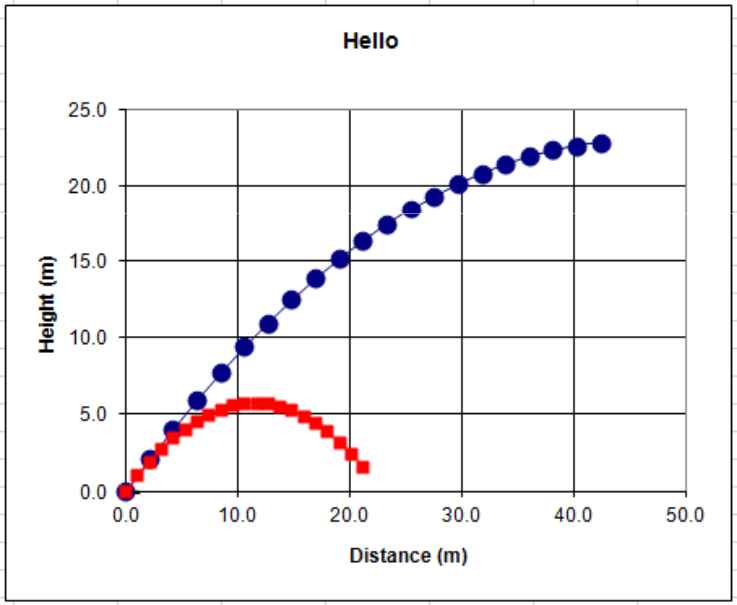
- Can you calculate the path of a rocket before the launch?
- Where will a random walker be after 100 steps?
- Where is the most likely square to land in Monopoly?
- Should you hit in Blackjack with a King 2 against a dealer's 5?

Many other simulations: car/flight safety, racing car redesign, oil exploration, Internet fraud checking, DNA sequencing, portfolio risk analysis, hurricane touchdown locations, climate-change predictions, and even potato chip design.

Projectile motion
Launching a rocket

v0 | 30

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1										maximum	22.8	meters				
2		v0	30	m/s		15	m/s			height						
3		theta	45	degrees		45	degrees									
4		a	-9.8	m/s2		-9.8	m/s2			time at	2.2	seconds				
5										maximum height						
6		Time	Distance	Height		Distance	Height									
7		t	x	y		x	y			furthest	91.8	meters				
8		(sec)	(m)	(m)		(m)	(m)			distance						
9																
10		0.00	0.00	0.00		0.00	0.00									
11		0.10	2.12	2.07		1.06	1.01									
12		0.20	4.24	4.05		2.12	1.93									
13		0.30	6.36	5.92		3.18	2.74									
14		0.40	8.49	7.70		4.24	3.46									
15		0.50	10.61	9.38		5.30	4.08									
16		0.60	12.73	10.96		6.36	4.60									
17		0.70	14.85	12.45		7.42	5.02									
18		0.80	16.97	13.83		8.49	5.35									
19		0.90	19.09	15.12		9.55	5.58									
20		1.00	21.21	16.31		10.61	5.71									
21		1.10	23.33	17.41		11.67	5.74									
22		1.20	25.46	18.40		12.73	5.67									
23		1.30	27.58	19.30		13.79	5.51									
24		1.40	29.70	20.09		14.85	5.25									
25		1.50	31.82	20.79		15.91	4.88									
26		1.60	33.94	21.40		16.97	4.43									
27		1.70	36.06	21.90		18.03	3.87									
28		1.80	38.18	22.31		19.09	3.22									
29		1.90	40.31	22.62		20.15	2.46									
30		2.00	42.43	22.83		21.21	1.61									
31																
32																
33																
34	pi	3.142														
35	the	0.785														
36																
37																



ROCKET

Where will I be after 100 steps (left or right)?

Probability

A "random walk"

Pascal explains the probability

1
1 2 1
1 3 3 1
1 4 6 4 1
1 5 10 10 5 1
1 6 15 20 15 6 1

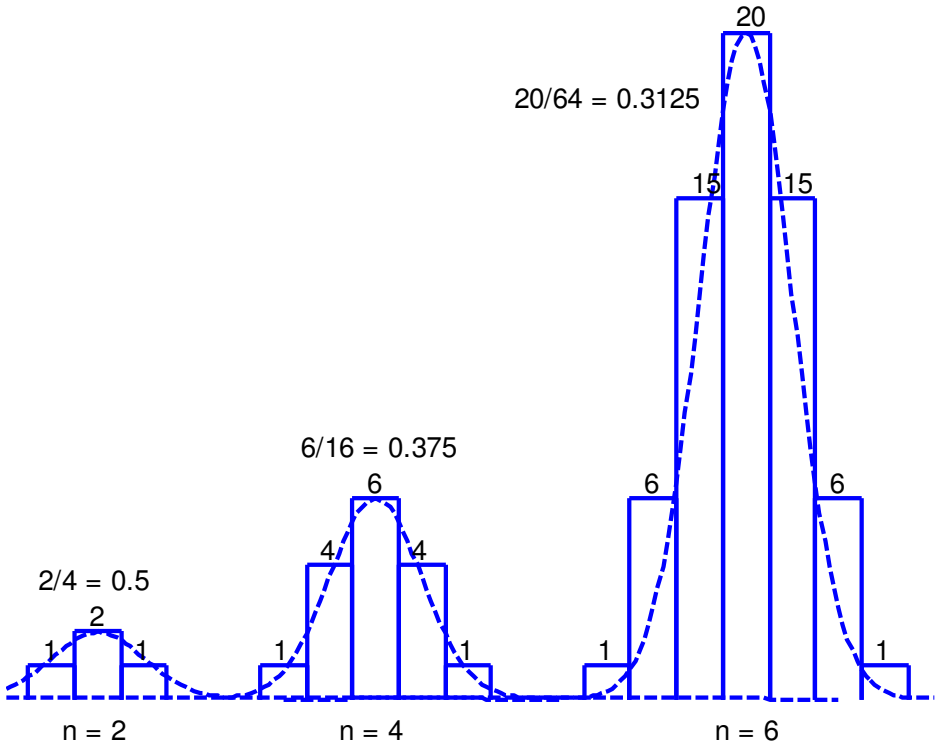
add two numbers from above

1 5

6

1 right, 5 wrong
'6 choose 1' = 6
= 6!/1!/5!

$$= \frac{6 \times 5 \times 4 \times 3 \times 2 \times 1}{1 \times 5 \times 4 \times 3 \times 2 \times 1}$$



Why the average person is not the most likely person.

4. Some computer applications

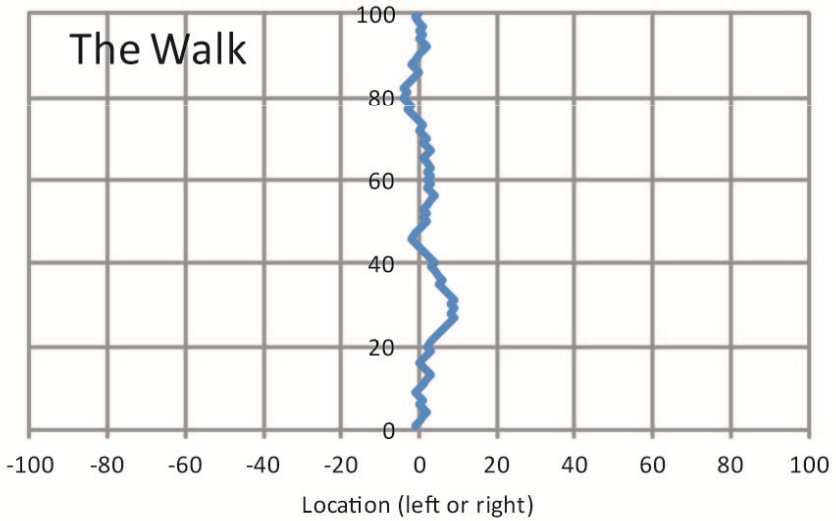
Where will I be after 100 steps (left or right)?

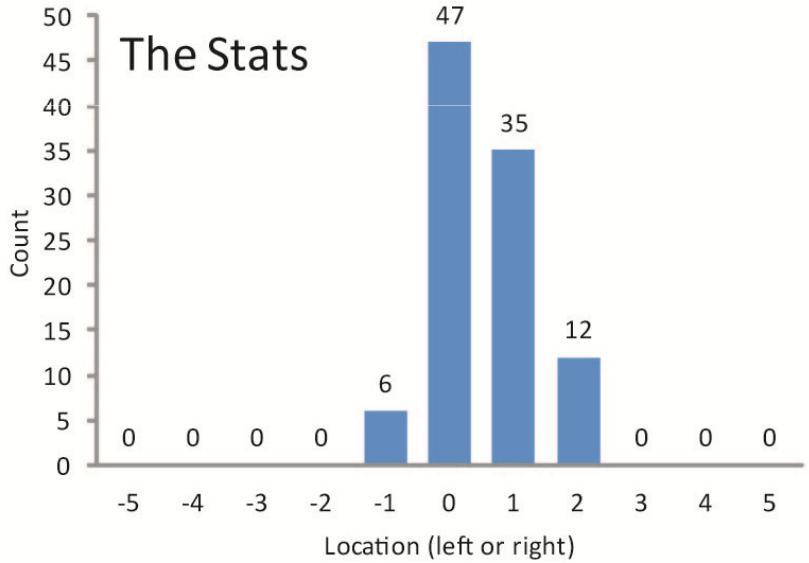
Probability

A "random walk"

A person takes a **random** step left or right out of a door and continues for 100 more steps.

Q1. Where is the most likely final location?
Q2. Is there a symmetry to the distances (i.e., the histogram of data)?
Q3. Why is the walker nor always in the middle?
Q4. How does the distribution change if you change the bias factor?



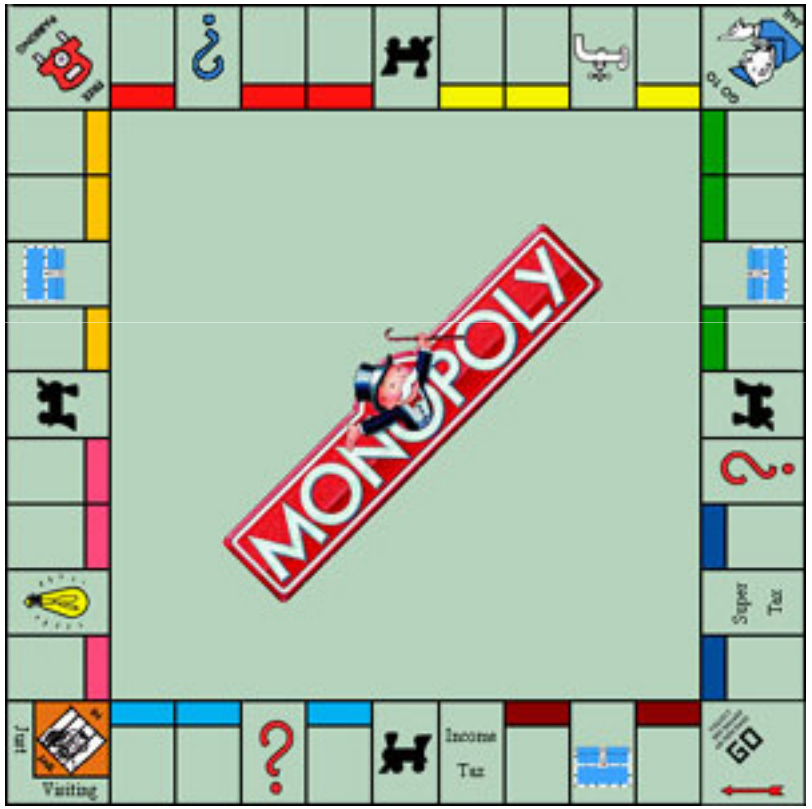


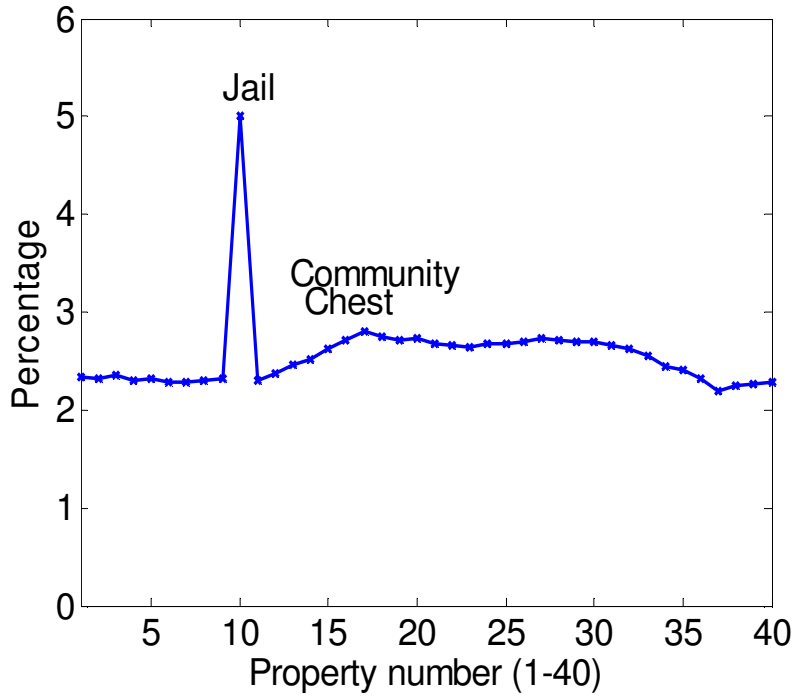
c.f. coin flips, roulette spins, stock market ticks, the weather, fusion reactor stability, . . .

WALK

Monte Carlo
Dice simulations

Modulo arithmetic: 40 repeated squares.
Over 1 million dice throws took 30 seconds.

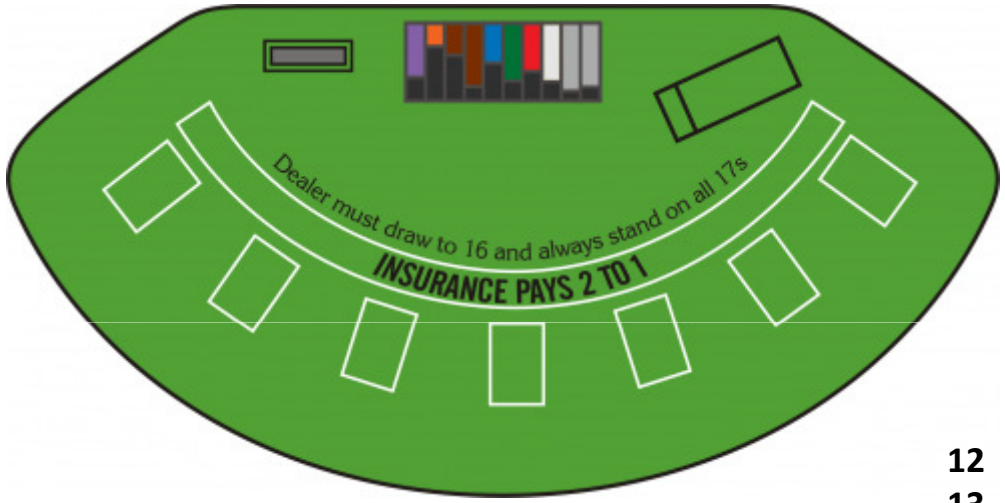




Which are the best properties?

Monte Carlo
Card simulations

Modulo arithmetic: 4 suits, 13 card/suit.
25,000 hands were dealt and took 2 minutes.



Player's card total	Dealer's up card									
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**A**
12	.42	.40	.44	.52	.47	.30	.29	.31	.23	.26
13	.41	.38	.41	.49	.48	.29	.21	.23	.24	.23
14	.40	.46	.46	.48	.46	.27	.20	.24	.21	.22
15	.38	.45	.48	.48	.46	.30	.24	.31	.23	.25
16	.42	.44	.44	.48	.51	.30	.24	.20	.22	.28
17	.51	.47	.46	.53	.57	.50	.28	.22	.26	.29
18	.53	.70	.64	.66	.59	.75	.66	.38	.38	.54
19	.76	.79	.72	.81	.66	.88	.92	.65	.56	.54
20	.87	.87	.85	.86	.88	.92	.90	.92	.81	.62
21	1	1	1	1	1	1	1	1	1	1

5. Some useful links/references

The Science Museum (London): Napier's Bones, Pascalina, Babbage's Analytical Engine.

Columbia University Computing History (New York): Jacquard loom, Herman Hollerith, IBM, the first "PC." http://www.columbia.edu/cu/computinghistory/

NASA: Sputnik telemetry. www.hq.nasa.gov/office/pao/History/sputnik/

NASA: Neil Armstrong and Apollo. http://www.hq.nasa.gov/alsj/a11/a11.step.html

John Naughton, "A Brief History of the Future -- The Origins of the Internet," Weidenfeld and Nicolson, London, 1999.

Sarah Flannery, "In Code," Profile Books, London, 2000.

John K. White, "Do the Math: On Growth, Greed, and Strategic Thinking," Sage, CA, 2012.
http://www.johnkwhite.ie/ http://www.uk.sagepub.com/books/Book236964/