“A CPU is literally just a rock we tricked into *thinking*”

@daisyowl

James Wu
University of Washington
Institute of Neuroengineering

So what is thinking?

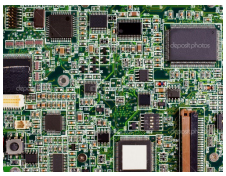
1000bulbs.com

bestbuy.com

Applied power

bestbuy.com

Power ⟶ Information



gettyimages

4

Power ⟶ Information

How did this happen?

5

Power ⟶ Information

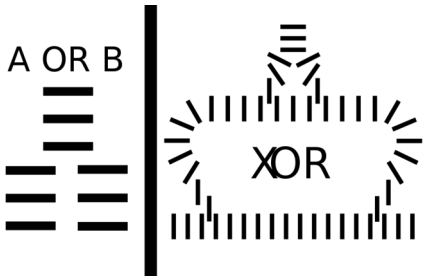
How did this happen?

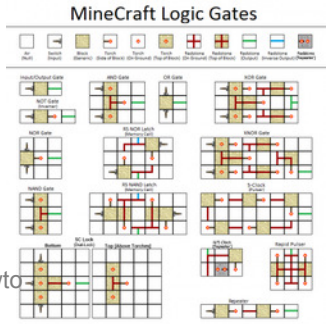
Repeating the same motif

New materials, methods ⟶ New ways of doing old things

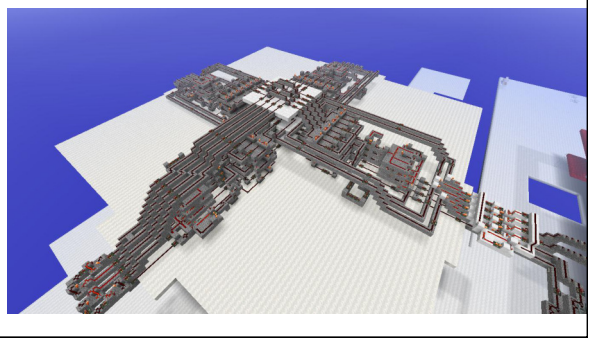
6

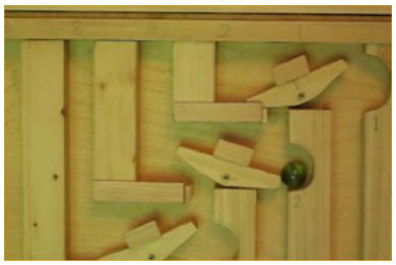
Youtube Lisa Chan Brown



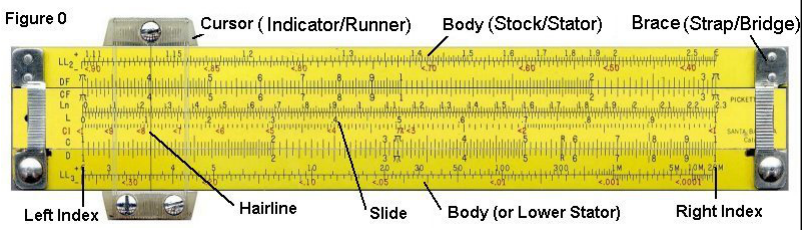


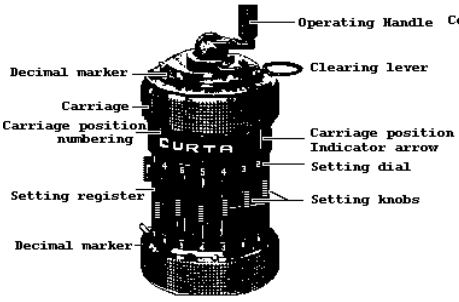
Minecraft wonderhowto



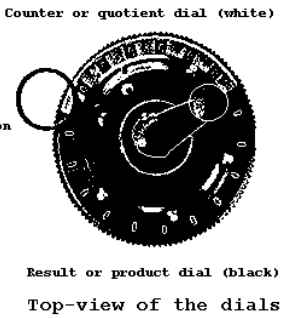


Marble computers





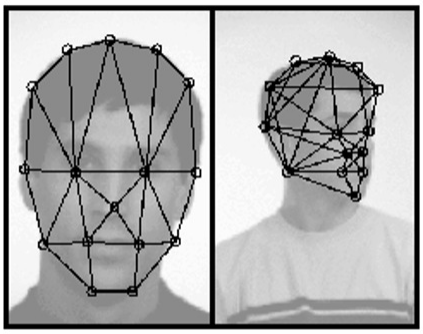
View of the CURTA



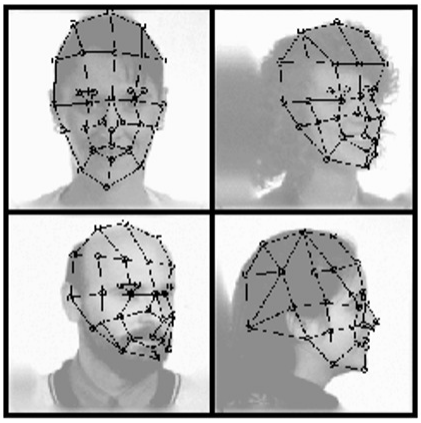
Top-view of the dials

Matthias Wandal

8



grids for face finding



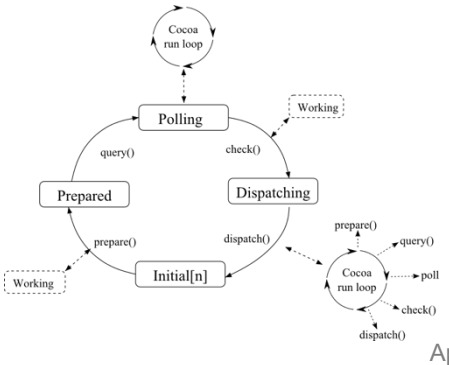
grids for face recognition

extremetech

An Alien Architecture

Silicon:

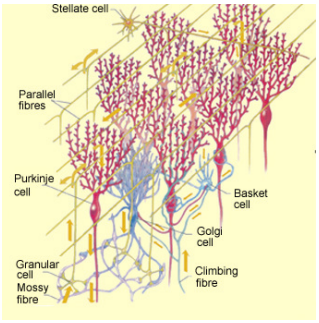
Simple operations, instantaneous results:
sequential architecture



Apple

Neurons:

Complex operations, slow results:
tremendously parallel architecture



Research

Huge performance difference

Daniel Leidner and Alexander Dietrich
https://www.youtube.com/watch?v=jglwgcz8iaM

https://www.youtube.com/watch?v=usAWvTKpIIs

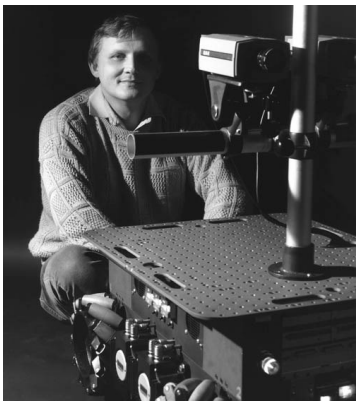
11

Research

Moravec's Theorem

"…it is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility."

Hans Moravec, Carnegie Mellon, 1980s



Hans Moravec, Carnegie Mellon 1995

12

Research

Why does it matter?

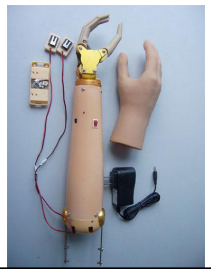
Amputation affects:

2 million patients (USA) 5 million with some paralysis

Standard of care:

poorly-controlled prosthetics

University of Alberta



Origin Instruments

13

Research

The hard problem:

Done

Not done

iStockPhoto

14

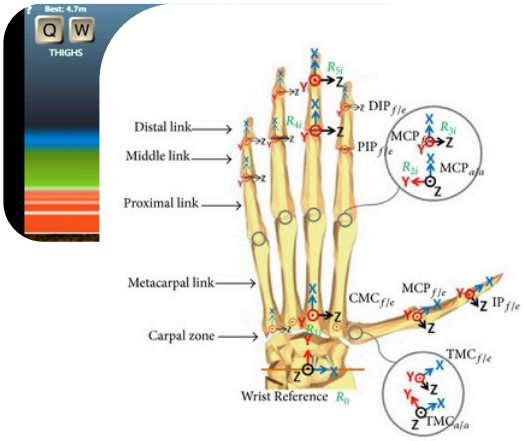
Research

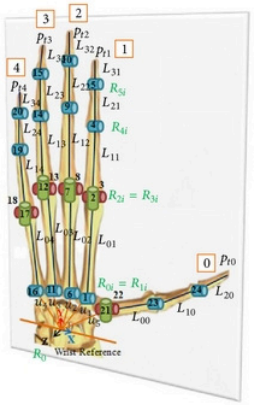
Split Hook

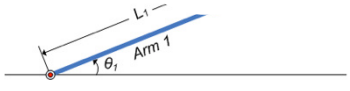
Sean McHugh, Youtube

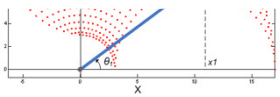
15

The Control Problem







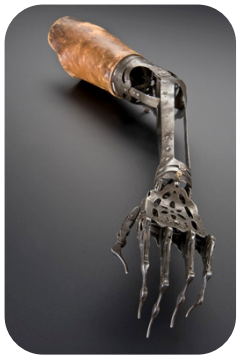


QWOP, Mathworks

Augmenting humans isn't new

Ancient Egypt

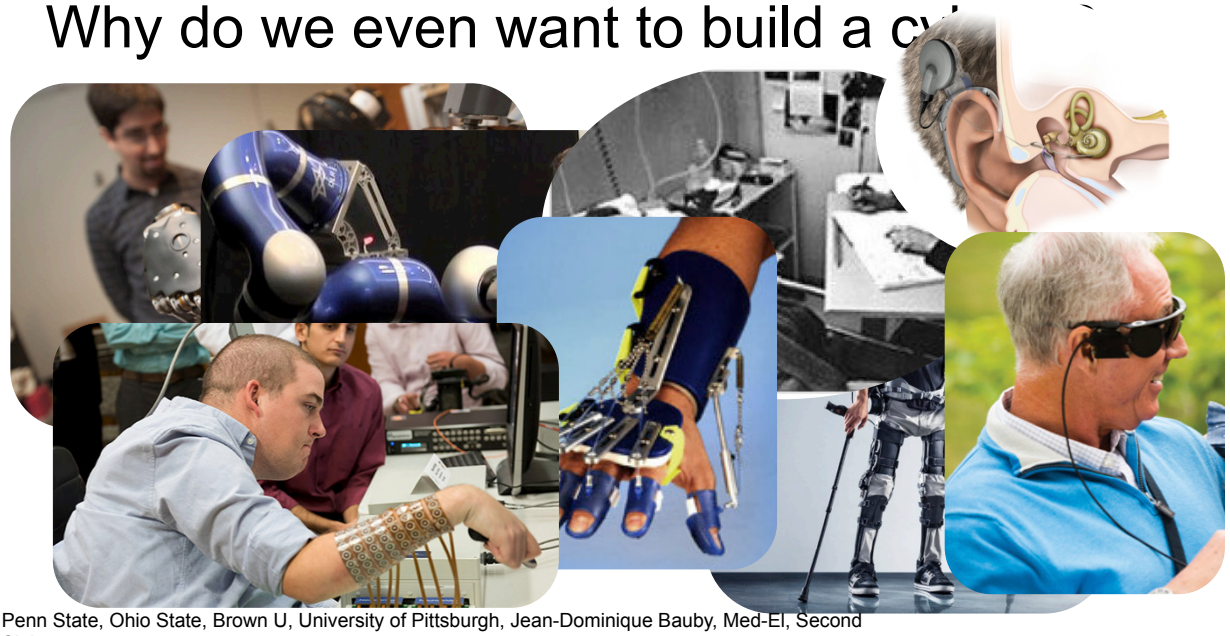
1500s Europe



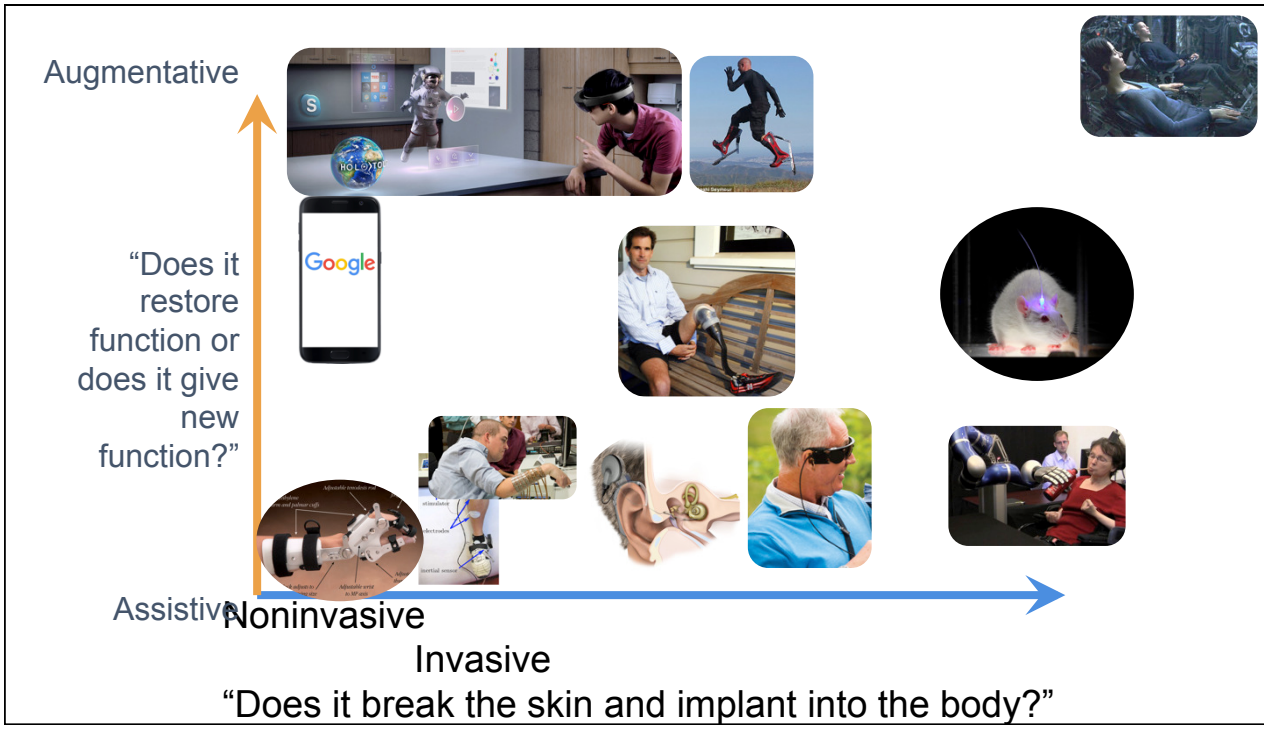
Victorian England
Ear trumpet (1700s)

Civil War

Why do we even want to build a cy

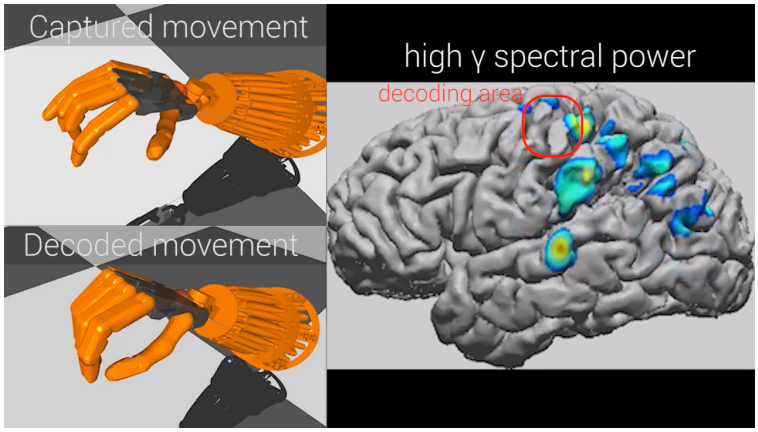


Penn State, Ohio State, Brown U, University of Pittsburgh, Jean-Dominique Bauby, Med-El, Second



Research

Electrocorticography



20

What have we accomplished?

21

Research

State of the Art

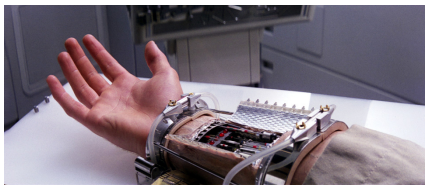
Current:

Switch-controlled low-dexterity prosthetic

DEKA Research

Future:

Volitionally-controlled dexterous prosthetic

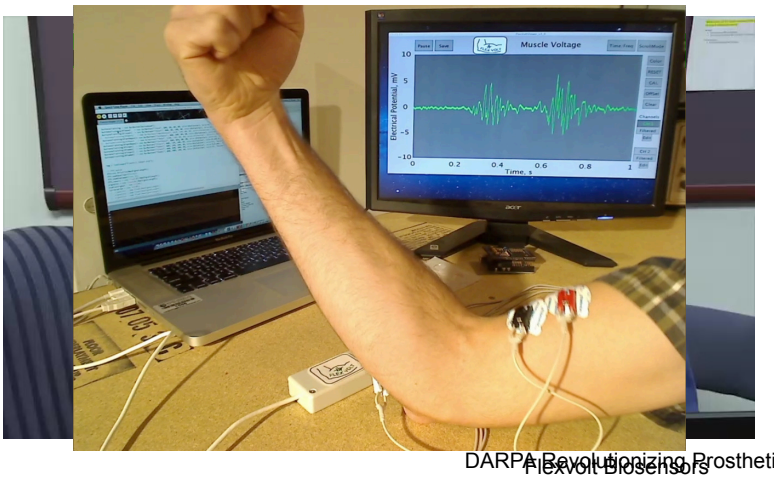


Star Wars Empire Strikes Back® LucasArts™

22

Research

Electromyography

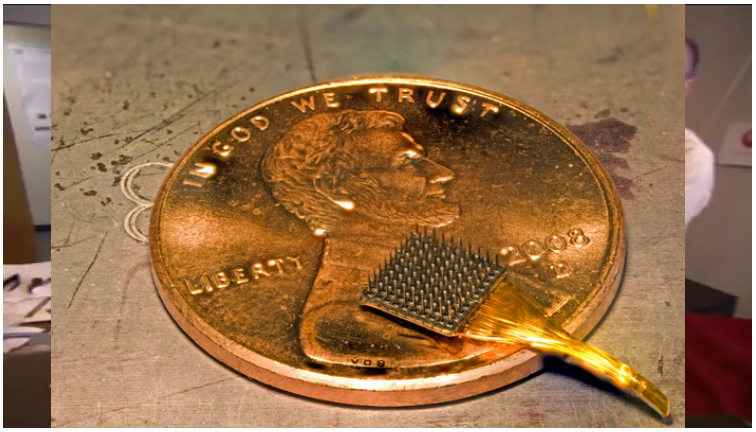


DARPA Revolutionizing Prosthetics
Flexvolt Biosensors

23

Research

Utah Array

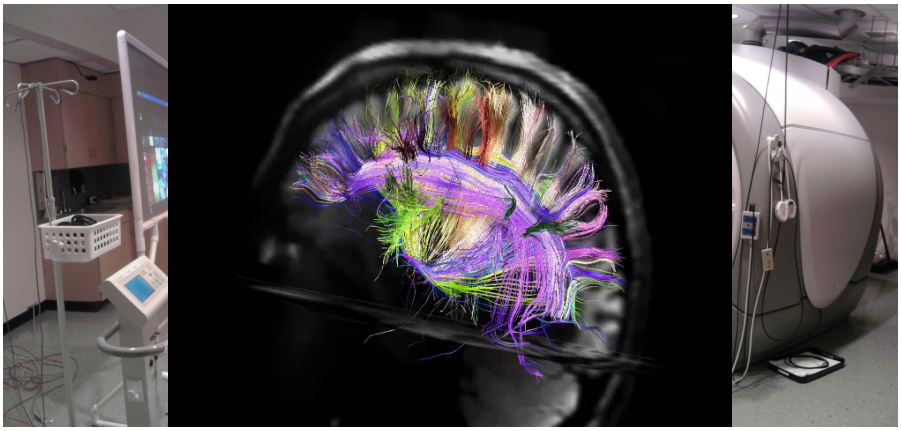


University of Pittsburgh Medical Center
Blackrock Microsystems
Minutes

24

Research

Tractography



Massachusetts General Hospital

25

Research

Deep Brain Stimulation

National Institutes of Mental Health

26

But…

27

Research

Where is the problem?

Signal capture	electronic noise coupled interference spatial resolution temporal resolution coverage
Signal processing	frequency resolution time resolution
Feature extraction	event aggregation phase mixing spatial overlap
Model building	lacking mechanism lacking coordinate space lacking analytical solution

Everywhere.

28

29

30

31

- Kick for d > 50 mm

$$W_K = c_k(\ln(d_A) - \ln(d_E))$$

- Bond[2] for 50 mm > d > 0.05 mm

$$W_B = c_B\left(\frac{1}{\sqrt{d_E}} - \frac{1}{\sqrt{d_A}}\right)$$

- Von Rittinger for d < 0.05 mm

$$W_R = c_R\left(\frac{1}{d_E} - \frac{1}{d_A}\right)$$

with W as grinding work in kJ/kg, c as grinding coefficient, d_A as grain size of the so

A reliable value for the grain sizes d_A and d_E is d_{80}. This value signifies that 80% (r literature. To calculate the KICK's and Rittinger's coefficients following formulas can

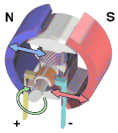
$$c_K = 1.151 c_B (d_{BU})^{-0.5}$$

$$c_R = 0.5 c_B (d_{BL})^{0.5}$$

with the limits of Bond's range: upper d_{BU} = 50 mm and lower d_{BL} = 0.05 mm.

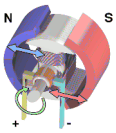
Motif:

Force ⟶ Rotation ⟶ Abrasion ⟶ Fracture



32

Power



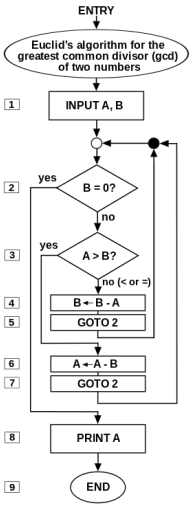
Information

?

33

Research

Because algorithms



Karatsuba multiplication

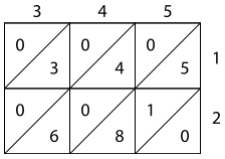
1.compute $x_1 \cdot y_1$, call the result A
2.compute $x_2 \cdot y_2$, call the result B
3.compute $(x_1 + x_2) \cdot (y_1 + y_2)$, call the result C
4.compute $C - A - B$, call the result K; this number is equal to $x_1 \cdot y_2 + x_2 \cdot y_1$
5.compute $A \cdot 100 + K \cdot 10 + B$.

34

Longhand

```
      23958233
×         5830
──────────────
      00000000  ( =      23,958,233 ×      0)
     71874699   ( =      23,958,233 ×     30)
    191665864   ( =      23,958,233 ×    800)
+ 119791165     ( =      23,958,233 × 5,000)
──────────────
  139676498390  ( = 139,676,498,390          )
```

Lattice Multiplication



35

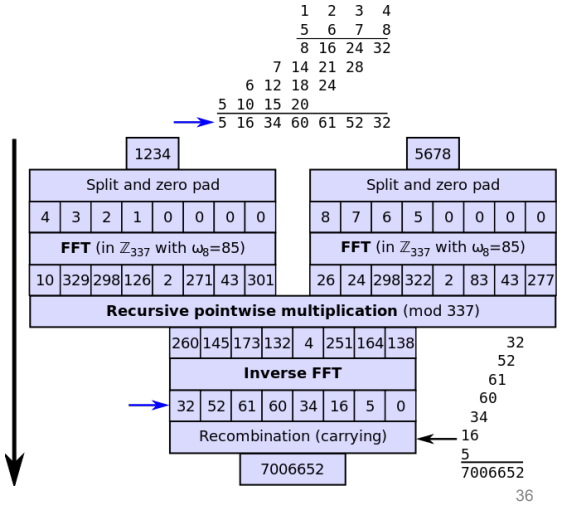
Peasant multiplication

$$
\begin{aligned}
3 \times 11 &= 3 \times (1 \times 2^0 + 1 \times 2^1 + 0 \times 2^2 + 1 \times 2^3) \\
&= 3 \times (1 + 2 + 8) \\
&= 3 + 6 + 24 \\
&= 33.
\end{aligned}
$$

A more complicated example, using the figures from the earlier examples (23,958,233 and 5,830):

```
Decimal:                Binary:
5830  23958233          1011011000110  1011011011001001011011001
2915  47916466          101101100011   101101101100100101110010
1457  95832932          10110110001    101101101100100101101100100
728   191665864         1011011000     1011011011001001011011001000
364   383331728         101101100      10110110110010010110110010000
182   766663456         10110110       1011011011001001011011001000000
91    1533326912        1011011        101101101100100101101100100000000
45    3066653824        101101         101101101100100101101100100000000
22    6133307648        10110           1011011011001001011011001000000000
11 12266615296          1011           101101101100100101101100100000000000
5  24533230592          101            101101101100100101101100100000000000
2  49066461184          10             1011011011001001011011001000000000000
1  98132922368          1              10110110110010010110110010000000000000
   ──────────                             1022143253354344244353353243222210110 (before carry)
   139676498390                          10000010000101010111100011100111010110
```

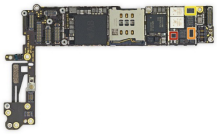
Schönhage–Strassen algorithm



36

Research

What's inside?



How did they make what's in

Why do they make it that way?

37