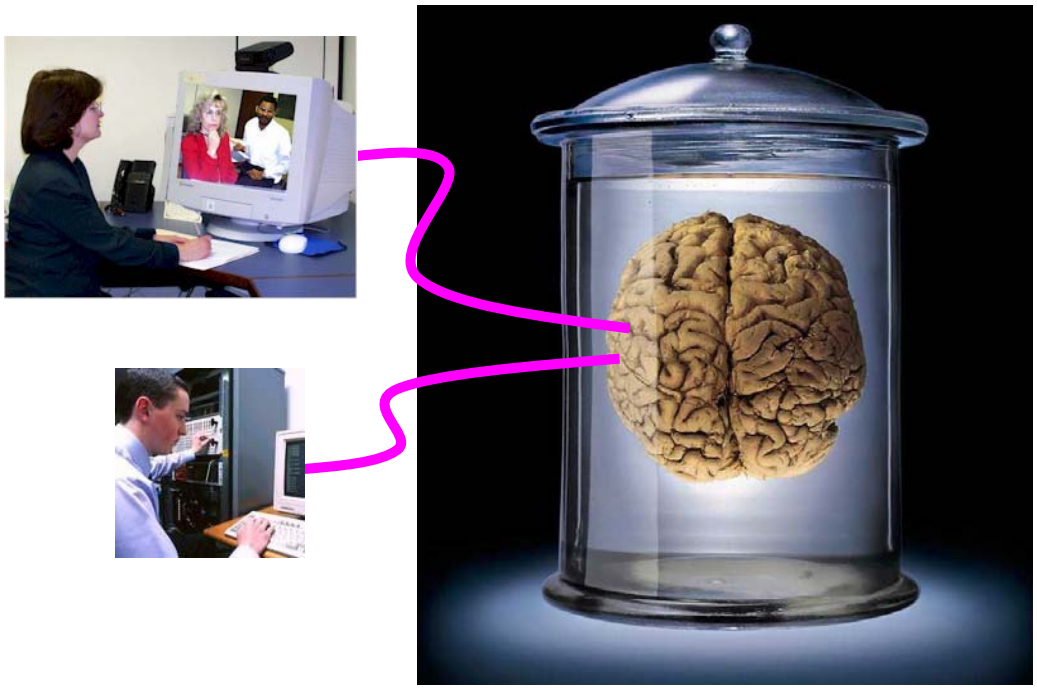
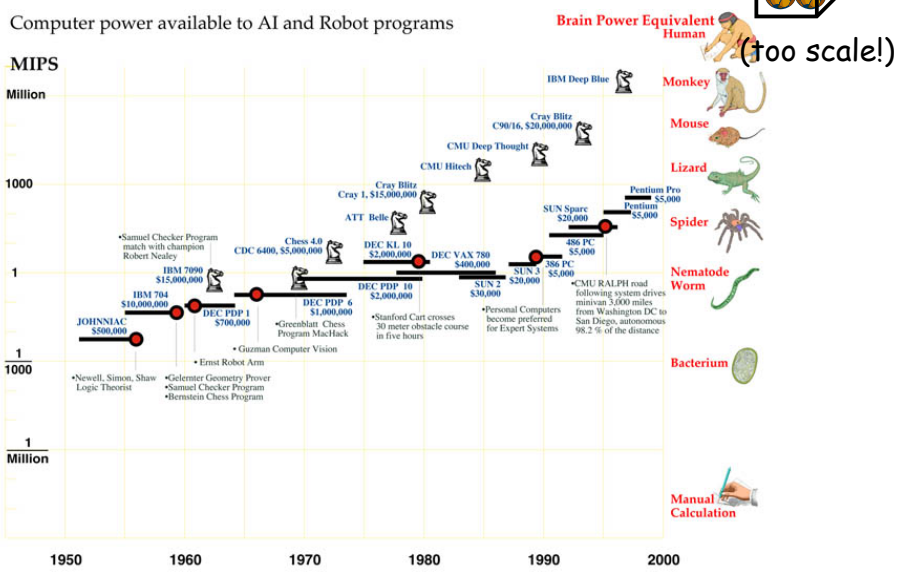
Brain in a Bottle

Seth Copen Goldstein
seth@cs.cmu.edu
Carnegie Mellon University



Brain Power?

(too scale!)

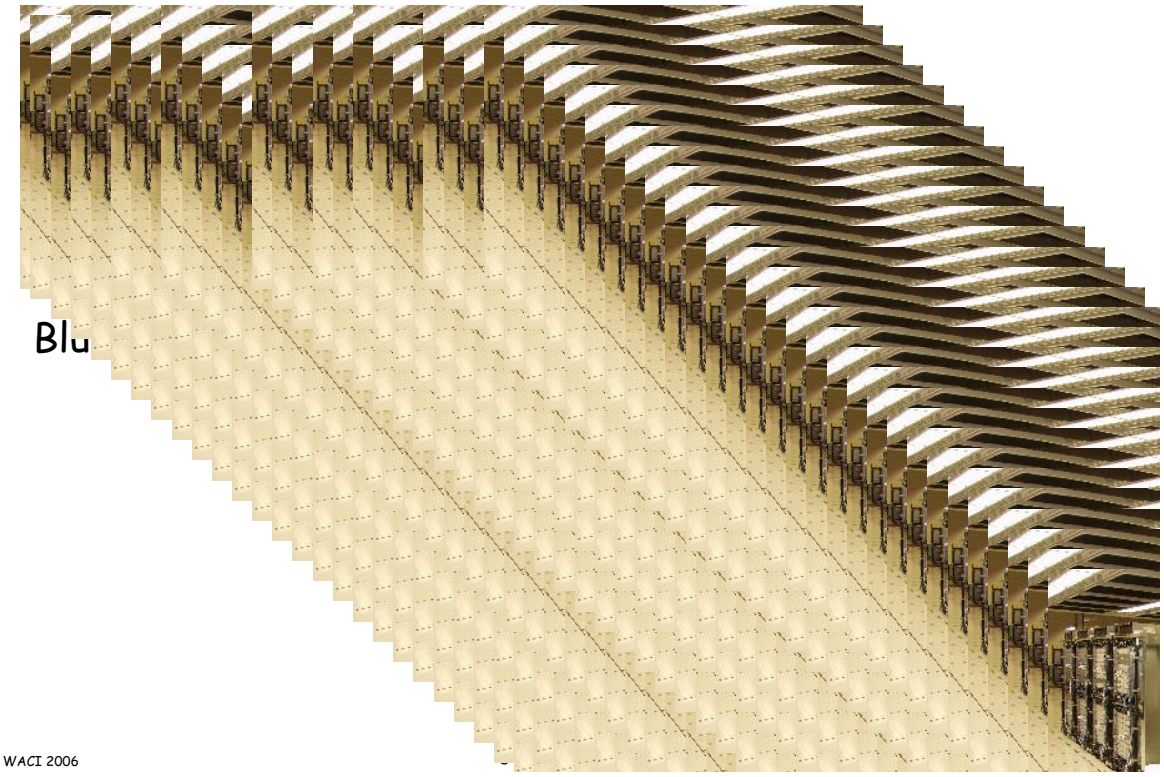


From Hans Moravec's Book "Robot"

Why not just more of the same

Blue Gene today ~ 10^9 MIPS

Why not just more of the same



Why not just more of the same

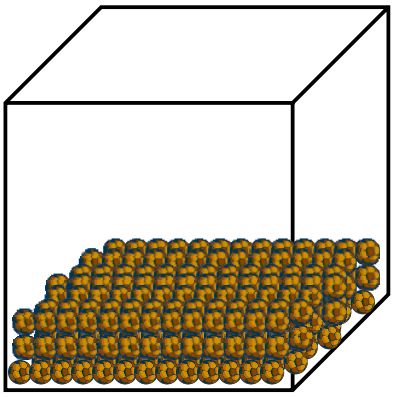
Blue Gene today ~ 10^9 MIPS (But in flops)

More importantly, connectivity
- Brain has ~10^5 connections between each neuron
- Total connections ~10^{14}

Power, volume – won't even go there

How to build it

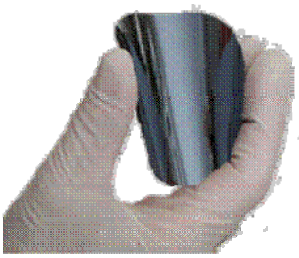
- 1mm^3 (self-assembled) processing unit
- Drop them into a bottle
- They self-assemble into a single massively parallel processor
- Issues:
  - How build units?
  - Power?
  - Interconnect?
  - How cool ensemble?
  - And, one more I won't address.



A potential approach

- How to form 3D from a 2D process?
  - begin with foundry CMOS on SOI

Reid, AFRL

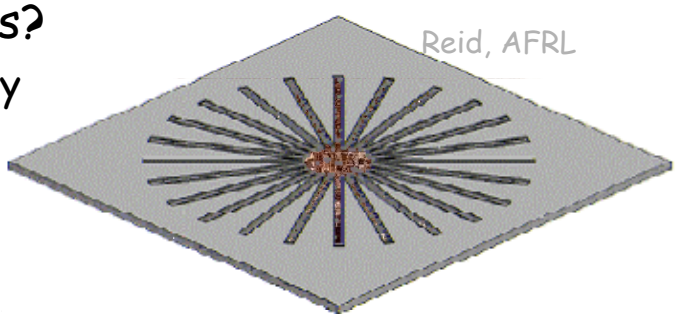


http://www.compart-tech.co.uk/

A potential approach

- How to form 3D from a 2D process?
  - begin with foundry CMOS on SOI
  - pattern a flower that includes structure and circuits

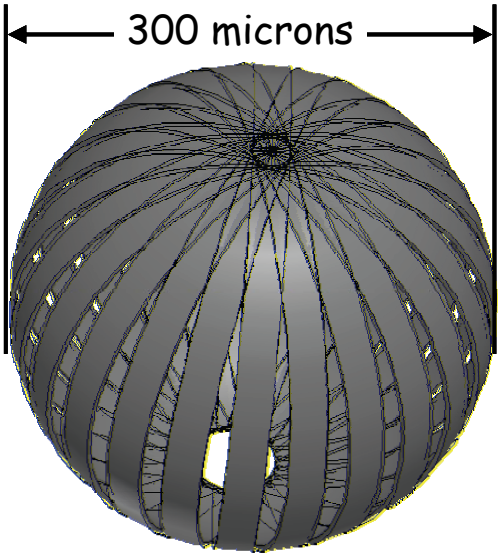
Reid, AFRL



A potential approach

- How to form 3D from a 2D process?
  - begin with foundry CMOS on SOI
  - pattern a flower that includes structure and circuits
  - lift off silicon layer
    - flexible
    - harness stress to form a sphere

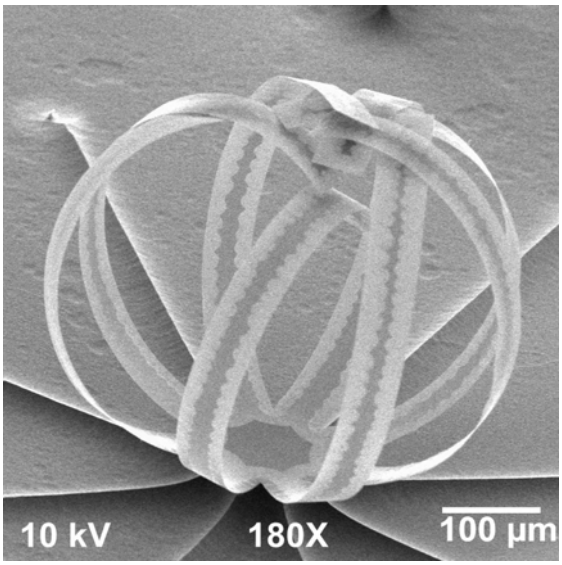
Reid, AFRL



A potential approach

Reid, AFRL

- How to form 3D from a 2D process?
  - begin with foundry CMOS on SOI
  - pattern a flower that includes structure and circuits
  - lift off silicon layer
    - flexible
    - harness stress to form a sphere

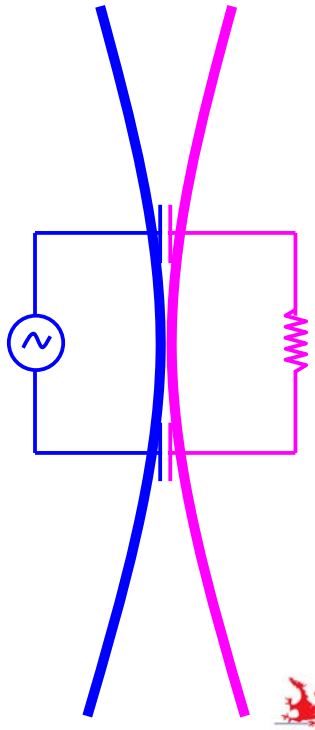


What it contains

- Using 90nm SOI process
  - ARM 7 (.25mm^2, 50µW/MHz)
  - 256KB memory (14 µW/MHz)
  - Circuits for power distribution
  - Energy for ~10^9 instructions
- These are today's numbers!

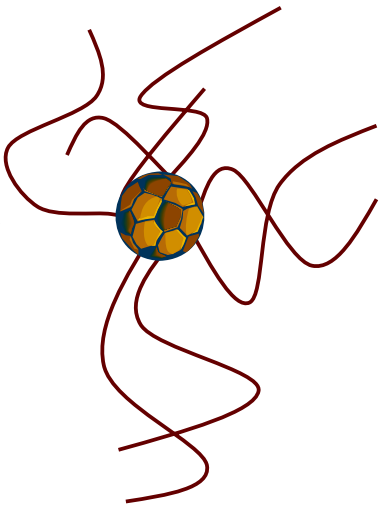
Delivering Power

- Each unit has a supercap
- Units are in contact with each other
- Use Capacitive Coupling
  - Direct unit-unit coupling
  - A "store & forward" network!
- Key: Packets of power
  - Network routing problem



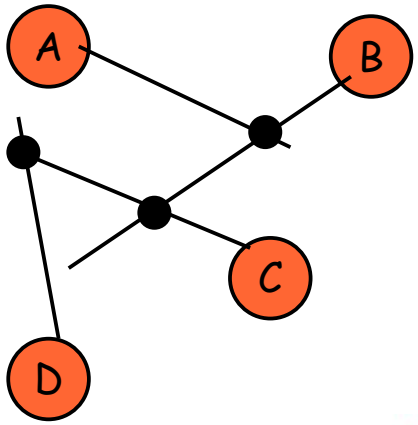
Connectivity

- So far, an examip machine, but only local connections.
- Attach to the surface wires of random lengths averaging 10cm in length
- Wire are coated with
  - Insulator
  - High-resistive coating



Connections

- A node can communicate with another node that is 1 or 2 contacts away.
- Example:
  - A can talk to B & C
  - D can talk to C & B
  - D interferes with A & C
- For 10cm lengths and uniform distribution, we get 400^2 neighbors per node.



Interference

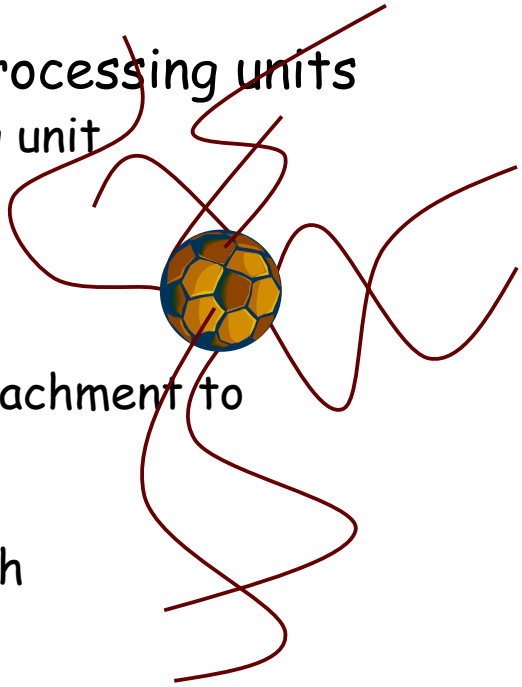
- Think of the wires as wave guides or antennas for VERY low power wireless.
- Communication will have to be sparse on each wire or this probably won't work

Volume and Power

- Using reasonable wires (<3Ω) and 1mm diameter spheres in $1m^3$ we have
  - ~50% volume in spheres
  - ~20% volume in wires
  - Rest for coolant
- Liquid cooled
  - 500pa pump delivering FC-77 will keep this cool.
  - Easily get more pressure and increase performance of each node

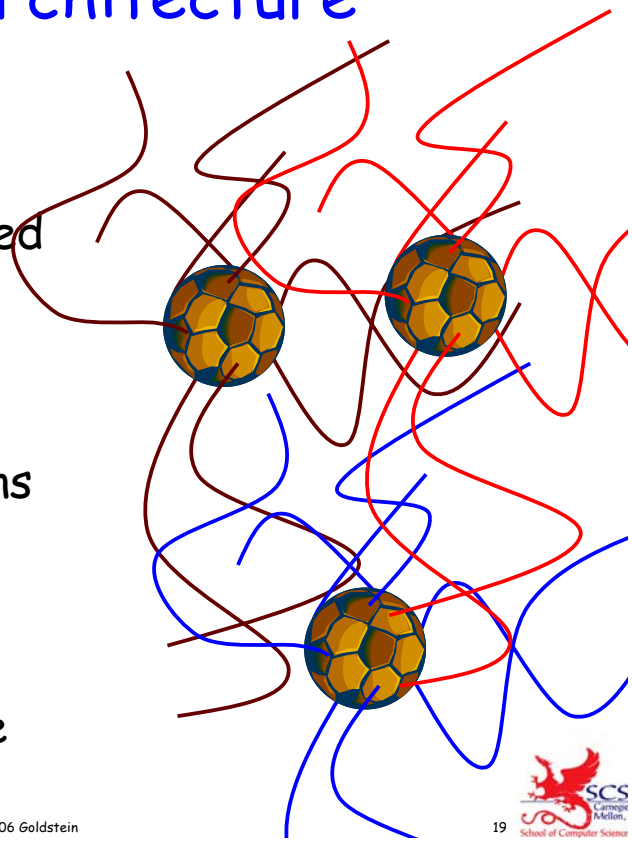
Goal: Brain-like hardware

- $1mm^3$ footprint for processing units
  - 10-100Mhz processing unit
  - Communication
  - Power distribution
- Attached wires
  - Non-deterministic attachment to surface
  - ~6 wires per node
  - Average 10cm in length
- Put in a bucket



System Architecture

- Hardware:
  - Random Network
  - Highly interconnected
  - Capacitive coupling
  - I/O at the edges
  - 10^{11} MIPS
  - 10^{14} total connections
  - $1m^3$
- Software:
  - Whoops, I wasn't going to mention the software



Cost

- processed silicon cost is <.002$ per node
- 10^9 nodes cost ~20,000,000$
  - 200M$ for 1 sustained petaflop by NSF
  - So, BiaB is 1000X more cost effective!
- Build it once and then for a mere 10K$
  - 10^6 MIP machine on your dest!
  - (About as big as 

)

Why?

- **MREFC** to study/simulate/understand the brain
- Provide researchers with an exaflop machine with unprecedented connectivity
- Oh, and of course,

Why?

- **MREFC** to study/simulate/understand the brain
- Provide researchers with an exaflop machine with unprecedented connectivity
- Oh, and of course,
  Figure out how to program the darn thing

Diatribe

- We are victims of our own success
- Imagine the research proposal:
  "Eliminate all Spam"
  - very hard
  - very interesting (to us)
  - VERY mundane to everyone else

Diatribe

- We are victims of our own success
- Imagine the research proposal:
  "Eliminate all Spam"
  - very hard
  - very interesting (to us)
  - VERY mundane to everyone else
- We need ideas
  - That capture imagination
  - Stimulate interesting research
  - That provoke students (the best and brightest) to enter computer science

Brain in a bottle

- Can we build a brain?
- Can we program such a machine?
- Can we understand intelligence?
- Can we create hard AI?
- Can we put a petaflop on every desk?

- Should we try?