Hal in 2001: A Space Odyssey (1968)

https://www.youtube.com/watch?v=HwBmPiOmEGQ
Ex Machina (2015)
Within thirty years, we will have the technological means to create superhuman intelligence. Shortly after, the human era will be ended.
- Vernor Vinge 1993
The History

The ever accelerating progress of technology ... gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue.

- John Von Neumann 1950s
Do you think *human level* computer intelligence will most likely occur

A) within 10 years
B) 10-30 years
C) 30-100 years
D) never
Do you think the singularity (superhuman intelligence) will most likely occur

A) within 10 years
B) 10-30 years
C) 30-100 years
D) never
Predictions for human level AI

Median prediction: 2045

The end of humans?

…I fear the development of full artificial intelligence could spell the end of the human race.

-- Stephen Hawking

I think we should be very careful about artificial intelligence. If I had to guess at what our biggest existential threat is, it’s probably that.

-- Elon Musk

I am in the camp that is concerned about super intelligence. … I agree with Elon Musk and some others on this and don't understand why some people are not concerned.“

- Bill Gates
The Premise

Modified from Hans Moravec
**Thesis**
- Computers are getting faster (Moore’s law)
- Faster computers are smarter
- Therefore computers are getting smarter

**Antithesis**
- Crying ‘wolf’
- It’s easy to look smart but hard to be smart

**Synthesis**
- Different kinds of intelligence
- We are all cyborgs
Thesis: Brains vs. Computers

◆ Brain: memory and speed (high end estimates)
  - 100 billion neurons each with 10,000 synapses \( \rightarrow \) 1000 TB
  - Each neuron firing at 100 Hz \( \rightarrow \) \(10^{13}\) bits/sec
    - per synapse would be \(10^{17}\) bits/sec

◆ Computer: memory and speed
  - 100 GB RAM
  - CPU (2 GHz) \( \rightarrow \) \(10^{11}\) bits/sec

◆ Computer power doubles roughly every 18 months
  - giving a thousand-fold increase every 15 years

Prediction: in 15 years, a $1000 computer will have the compute power of a human brain

86 billion neurons in the human brain; 11 billion in cortex
Thesis: Brains vs. Computers

Brain memory

- 100 billion neurons each with 10,000 synapses ➔ 1000 TB
- 300 words/min * 2 bytes/word * 1/60 min/sec = 10 bytes/sec
- 30 years = 1 billion seconds
- ➔ 10 GB of words in a lifetime
- 0.1-100TB data (images) in a lifetime
- ➔ 10 TB is a better guess

Computer memory

- 10 TB = $300 on amazon
- But we want fast (on chip) memory
  - 5 GB/GPU ➔ 2,000 GPUs for 10 TB ($500,000—including GPU)
Thesis: Brains vs. Computers

◆ Brain speed
  ● 100 billion neurons * $10^4$ synapses firing at 100 Hz $\Rightarrow 10^{17}$ bits/sec
  ● Perhaps $10^{15}$ FLOPS

◆ Computer speed
  ● CPU $\Rightarrow 10^{11}$ bits/sec
  ● GPU: 1,000-5,000 gigaflops $\Rightarrow 10^{12}$ FLOPS

1,000 GPUs = 1 brain?
Moore’s law

- **Initially**: The number of transistors in an integrated circuit doubles roughly every two years.
- **More generally**: Compute power doubles every 18-24 months.

<table>
<thead>
<tr>
<th>Cray XMP - 1983</th>
<th>iPhone - 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mhz clock</td>
<td>1.3 Ghz clock</td>
</tr>
<tr>
<td>64 Meg RAM/32 Gig disk</td>
<td>64 Gig RAM</td>
</tr>
<tr>
<td>1.5 tons</td>
<td>4 oz.</td>
</tr>
<tr>
<td>250 Kilowatts</td>
<td>0.125 Watts</td>
</tr>
<tr>
<td>$35,000,000</td>
<td>$650</td>
</tr>
</tbody>
</table>

Not to scale
Moore’s law = exponential growth

- Currently: circa 1,000 GPUs to match a human brain
- 10,000-fold speed-up over the 20 years
  - i.e. doubling every 18 months
  
<table>
<thead>
<tr>
<th>1992</th>
<th>2012</th>
<th>Times improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>128 MB</td>
<td>144 GB</td>
<td>17,000</td>
</tr>
<tr>
<td>1-core 25 Mhz</td>
<td>12-core 3.5 Ghz</td>
<td>11,000</td>
</tr>
</tbody>
</table>

- At that rate a 1,000-fold speed-up will take 15 years
  - $2^{(15/1.5)} = 1,000$

Prediction: in 15 years, one GPU equivalent will have the compute power of a human brain
The end of Moore’s Law?

http://www.telegraph.co.uk/technology/2016/02/25/end-of-moores-law-whats-next-could-be-more-exciting/
But remember the longer story

GPUs!
GPUs work in parallel

https://www.youtube.com/watch?v=-P28LKWzrI

- For some tasks (e.g. deep learning) 10-50 fold speedup at only 2x the cost
  - I.e. runs at 10x the performance per dollar
    - for computation (same cost for memory)

But how does compute power translate into intelligence?

- 10 billion neurons in cortex
- 20 million neurons in cortex
- 100 million neurons
Chess Machine Performance versus Processing Power

Chess Rating

- Kasparov
- Grand Master
- Senior Master
- Master
- Expert
- Class A
- Class B
- Class C
- Class D
- Bernstein, IBM 704, 1957

Search depth, ply

Chess positions/second

Equivalent MIPS

- Cray Blitz, Cray C90/16, 1993
- Cray Blitz, Cray 1, 1981
- Beltech, 1985
- Hitech, 1985
- Deep Thought, 1989
- Deep Thought, 1991
- Deep Thought II, 1994
- Deep Blue, 1997

1996
- MacHack, PDP-10, 1970
- MacHack, PDP-6, 1966
- Chess 4.0, CDC 6400, 1973
- Chess 3.5, CDC 6400, 1971
- Chess 4.9, Cyber 176, 1979
- Chess 4.6, Cyber 176, 1977
- Chess 4.4, Cyber 176, 1975
- BELLE, 1978
- BELLE, 1983
- CHIPTEST, 1987
- Hitech, 1985
- DEEP THOUGHT II, 1994
- DEEP THOUGHT, 1989
- DEEP BLUE, 1997
- Deep Blue, 1997

1996
- Kasparov
- Grand Master
- Senior Master
- Master
- Expert
- Class A
- Class B
- Class C
- Class D
- Bernstein, IBM 704, 1957

Search depth, ply

Chess positions/second

Equivalent MIPS
# Speech Recognition

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price</strong></td>
<td>$5,000</td>
<td>$500</td>
<td>$50</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Vocabulary size</strong></td>
<td>1,000</td>
<td>10,000</td>
<td>100,000</td>
<td>$10^5$</td>
<td>$10^6$</td>
</tr>
<tr>
<td><strong>Continuous speech</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Minutes Training</strong></td>
<td>180</td>
<td>60</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>Poor</td>
<td>Fair</td>
<td>Decent</td>
<td>Better</td>
<td>Good?</td>
</tr>
</tbody>
</table>

From *The Singularity Is Near, p. 103 (updated)*
Artificial General Intelligence (AGI)

- Possible paths to AGI
  - Specialized AI and Machine Learning
  - Simulate Human Cognition (high level)
  - Simulate Brains (neural level)
  - Simulate Evolution

- What could weak Artificial General Intelligence do?
- What could superhuman intelligence do?

The Singularity: when computers are better at everything than people
What could weak AGI do?

- Watch everything you do
  - Where did I leave my keys?
  - Monitor the elderly
  - Eliminate crime
- Interactive entertainment
- Turn rough dictation into good text
What could a smart computer do?

- Anything anyone can do – but better
  - Not good for job security
- Design a really smart computer
- Solve aging
- Upload a copy of your brain
  - What would life be like if you could be copied?
- Destroy the world by mistake
Design a really smart computer

Using Machine Learning to Explore Neural Network Architecture

Use Reinforcement Learning to search for the ‘best’ neural net architecture

https://research.googleblog.com/2017/05/using-machine-learning-to-explore.html
Our Distorted View of Intelligence

EINSTEIN

Haha that's adorable
the funny robot can
do monkey tricks!

DUMB
HUMAN

AI
INTELLIGENCE

CHIMP
BIRD
ANT

Time
Haha that's adorable the funny robot can do monkey tricks!

The ??

Reality

Intelligence

EINSTEIN
DUMB HUMAN

CHIMP

BIRD

ANT

AI INTELLIGENCE

Time

waitbutwhy.com
The good, the bad and the bogus

- **A future so bright you’ll need sunglasses**
  - Marvin Minsky (and Ray Kurzweil)
- **The future doesn’t need us**
  - Bill Joy
- **Robots are our children**
  - Hans Morovic

I'm as fond of my body as anyone, but if I can be 200 with a body of silicon, I'll take it.
  - Danny Hillis
Antithesis

- The Singularity can’t happen because . . .
  - Moore’s law will end soon
  - Software isn’t improving as fast as hardware
  - AI has overpromised for 50 years
    - It is just a fantasy of old men who want to “upload”
      on to computers and live forever

Douglas Hofstadter on Kurzweil’s and Moravec’s books: “It’s as if you took a lot of very good food and some dog excrement and blended it all up so that you can't possibly figure out what's good or bad. It's an intimate mixture of rubbish and good ideas, and it's very hard to disentangle the two, because these are smart people; they're not stupid.”
Software improves slowly?

- Software improves slowly
  - I still run emacs because Word is still slow
  - Programmers still write 10-20 lines of code a day

- Software writing is massively faster
  - One line of matlab saves a month of programming in C
  - How long ago did it take 20 years ago to write a video game like Penn freshman do now right?
  - How long would it have taken 10 years ago to write a decent Google mash-up?
Overpromising

Machines will be capable, within 20 years, of doing any work a man can do.

- Herbert Simon 1956

Within a generation . . . the problem of creating ‘artificial intelligence’ will substantially be solved.

- Marvin Minsky 1967
Extrapolation is dangerous

In 1966 Time Magazine predicted

- By 2000, technology would have advanced enough that no one in America would work for a living.
- Each American would receive $30-$40,000 (1966) dollars every month simply for being American.
Intelligence is harder than it looks

Deep learning is a better ladder but a better ladder doesn't necessarily get you to the moon.

- Gary Marcus
It’s easy to look smart but hard to be smart

◆ Size isn’t everything
  ● Wikipedia knows more than you, but is it smart?
  ● What have computers ever invented?

◆ Understanding knowledge is hard
  1. Today was Jack’s birthday.
  2. Penny and Janet went to the store.
  3. They were going to get him a present.
  4. Janet decided to get a top.
  5. “Don’t do that” said Penny.
  6. “Jack has a top.
  7. He will make you take it back.”

Charniak ’72
The city council refused to give the students a permit for the demonstration because ...

1. they feared violence.
2. they advocated revolution.

Winograd ‘70
It’s the representation, stupid!

- Representations make reasoning easy or hard
  - IV + IX
  - IIII + IIIIIIIII
  - 4 + 9

- We only have representations for some problem types, and don’t know how to learn new ones
  - HMMs or deep learning for speech recognition
  - But what is the right representation for a scene? for a partnership? for love?

Some deep net people claim they can learn any representation
Most thought is simulation?

- I know how you feel by my feeling the same way
- I understand speech partly by “knowing” how a mouth and tongue would move to make the sounds
- I know how a frisbee will go by visualizing throwing it

<table>
<thead>
<tr>
<th>System 1</th>
<th>System 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactive</td>
<td>Reflective</td>
</tr>
<tr>
<td>Parallel</td>
<td>Sequential</td>
</tr>
<tr>
<td>Unconscious</td>
<td>Conscious</td>
</tr>
<tr>
<td>Embodied</td>
<td>Abstract</td>
</tr>
<tr>
<td>Emotion &amp; Simulation</td>
<td>Logic</td>
</tr>
</tbody>
</table>

Consequence: smart computers may need to simulate humans?
Synthesis: *Intelligence Amplification*

- There are different kinds of intelligence
  - Which is smarter:
    - A cat or a dog?
    - An octopus or an ant?
    - A computer or a person?

- Computers are in many ways smarter than us
  - How good are you at multiplication, playing chess or go, chip layout, gene sequencing, or airline scheduling?
  - But they are mostly still *much* dumber than us
  - They will gradually take over more functions
    - e.g., translation, surgery, driving cars, teaching, …
We are as in 19th C for artificial flight

Airplanes don’t fly like birds do.
Computers won’t think like humans do.
Universal components of intelligence?

- **Flight**
  - Power to weight ratio is key
  - Wing shape key for lower power to weight ratios

- **Intelligence**
  - Memory
  - Processing speed
  - What else??
We are already cyborgs

You can’t do much thinking with your bare brain
Will computers be our cortex?

Image credit: http://siimland.com/what-to-feed-your-neocortex-to-boost-brain-power/
Neither people nor AI are very smart?

- Current AI’s are very specialized
- Individual people don’t know very much and can’t do very much
  - Imagine being dropped by yourself on a nice desert island
- Societies are smart
  - And increasingly have humans working with AIs
Or maybe we are in a simulation?

- If Moore’s law continues and the singularity occurs, then (eventually) the entire 20th century of human life could be simulated on a home computer.
- So post-singularity, most people will be simulated.
- So we are probably ...

Would you like to run a simulation of the 20th Century with minor modifications to see what happens?
Qualia and Reality

Would you still experience the color red and the feeling of anger if …

1) Your retina were replaced with a high quality photo-receptor.
2) V1 was replaced with a high quality computer that simulates the neurons there.
3) V2 was further replaced with a simulation.
4) Your amygdala was replaced.
5) ¼ of the neurons in your brain were replaced.

A) Yes
B) No
Consequences

- If the singularity occurs
  - It is unclear what niche humans will occupy

Even if it takes twice as long as Kurzweil says (40 vs. 20 years) and is half as dramatic, the singularity, if it occurs, will be the biggest event of the 21st century (unless humans kill ourselves off first).
Consequences

- Even if no singularity occurs
  - Computers will get faster and smarter
  - Many jobs might go away
    - Secretaries, travel agents, store clerks, truck drivers
    - Lawyers, radiologists …
    - Computers will do to white collar jobs what the industrial revolution did to physical labor jobs?
      - But faster

https://www.youtube.com/watch?v=NrmMk1Myrxc
“about 47 percent of total US employment is at risk”

OECD: 14% lost

Forrester: 10% lost (net)
Many jobs are at risk

- US: over 4 million people drive for a living
- US: 4.5 million retail sales workers
- India: customer support, IT, ...

But mostly tasks are automated
Reality

- Job loss rate is (so far) unchanged
- Mostly *tasks*, not jobs are automated
ATMs did not replace bank tellers

James Bessen
Will AGI change our idea of what it is to be human?
What you should know

◆ A brain ~ 1,000-5,000 GPUs (in 2018)
  ● 1 brain ~ 10 TB ~ 2,000 GPUs (at 5 GB/GPU)
  ● 1 brain ~ $10^{15}$ FLOPS ~ 1,000 GPUs

◆ Exponential growth is non-intuitive
  ● Slow, then really fast
  ● Moore’s law = 1,000-fold increase every 15 years

◆ Consequences of the singularity
  ● Unbelievable scientific and economic progress
  ● Humans superseded??

◆ Controversy over if/when it will happen
  ● And what the consequences might be
Thank you!