Imperial College London

Imitating human behaviour with brain-inspired A.I.

A neuro-inspired take and beyond

Zafeirios Fountas

Royal College of Art – November 2017
Presentation available at zfountas.com

OLLY emotech

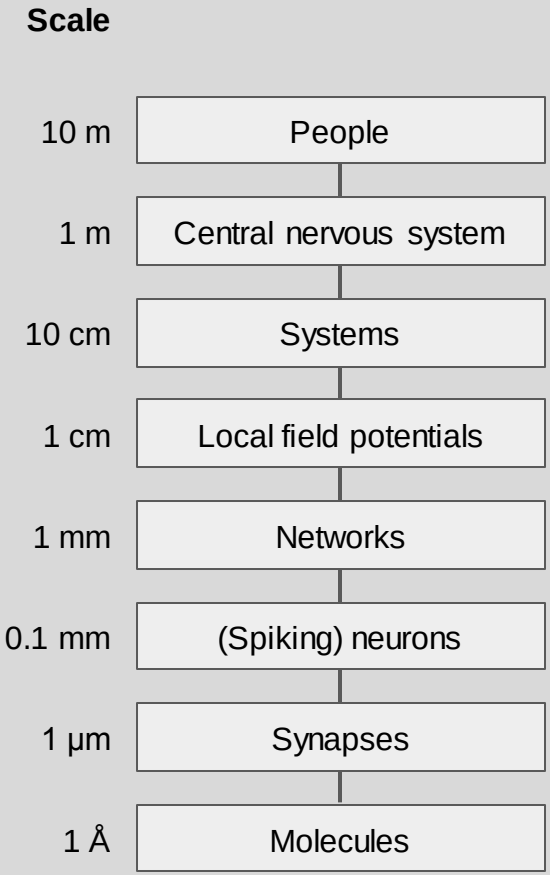
Why looking at brains?

- ➢ It is the only device we know that is truly intelligent!
- ➢ We could kill “multiple” birds with one stone.

We could potentially...

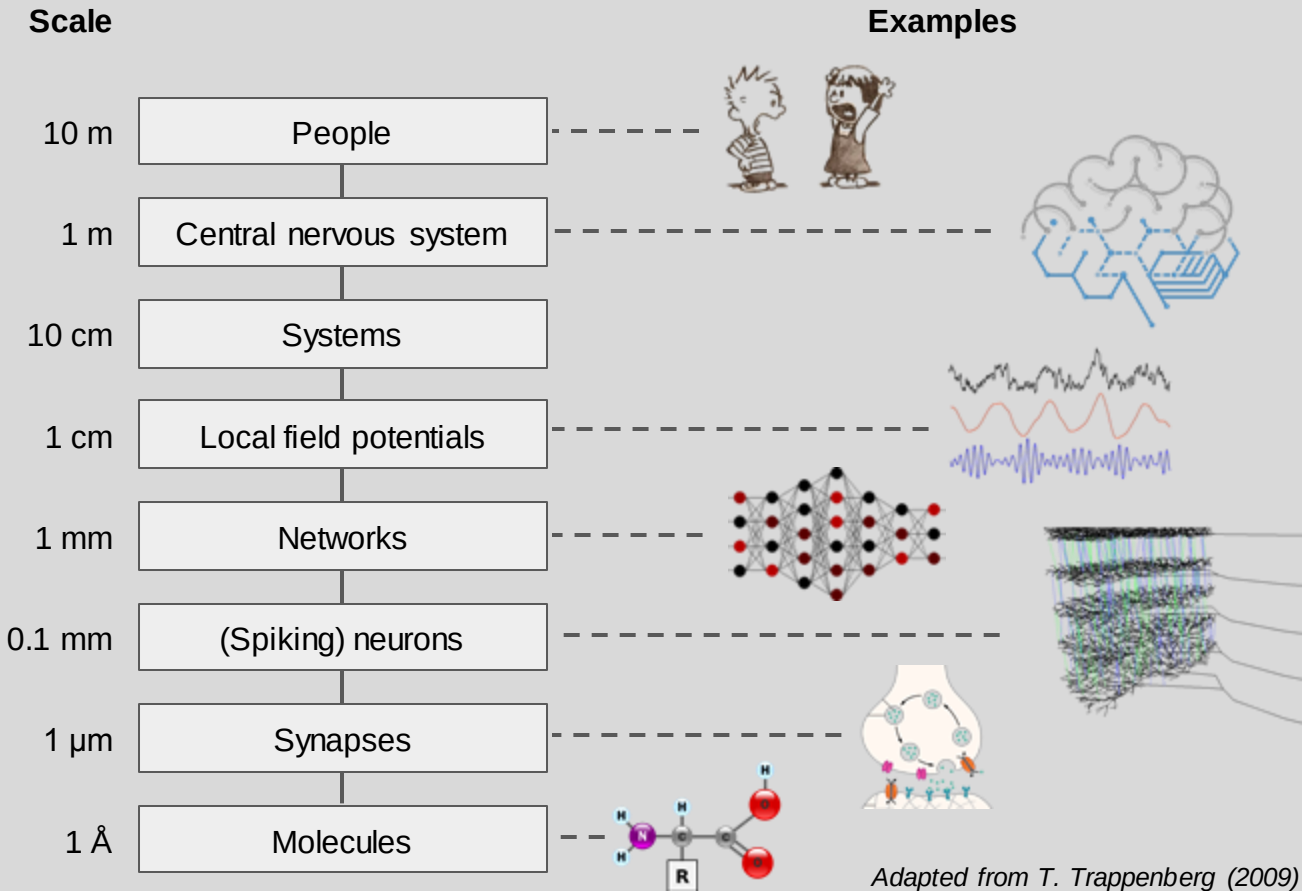
..copy mechanisms and make intelligent machines	..solve neural diseases *e.g. Alzheimer's, Parkinson’s, Huntington's, ...*	..understand better our own minds	..maybe even solve consciousness

Simulating the brain: Levels of abstraction



Adapted from T. Trappenberg (2009)

Simulating the brain: Levels of abstraction



Adapted from T. Trappenberg (2009)

Simulating the brain: Levels of abstraction

Bio- accuracy

low

high

Simulation speed

high

low

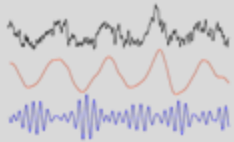
Scale

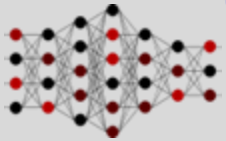
Examples

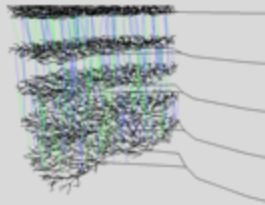
Scale	
10 m	People
1 m	Central nervous system
10 cm	Systems
1 cm	Local field potentials
1 mm	Networks
0.1 mm	(Spiking) neurons
1 µm	Synapses
1 Å	Molecules











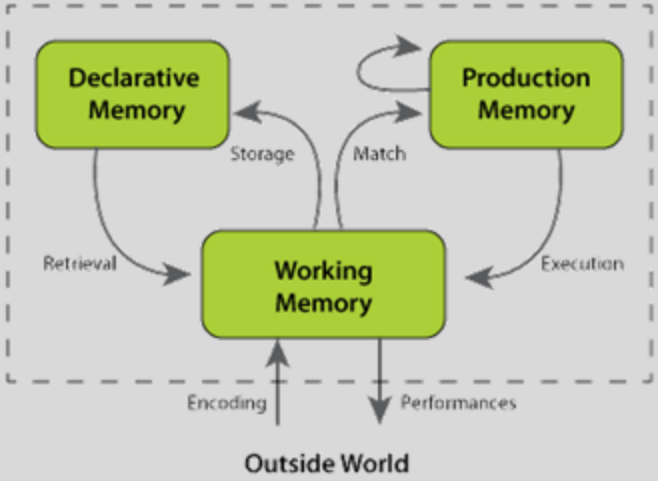




Adapted from T. Trappenberg (2009)

Types of brain-inspired A.I.

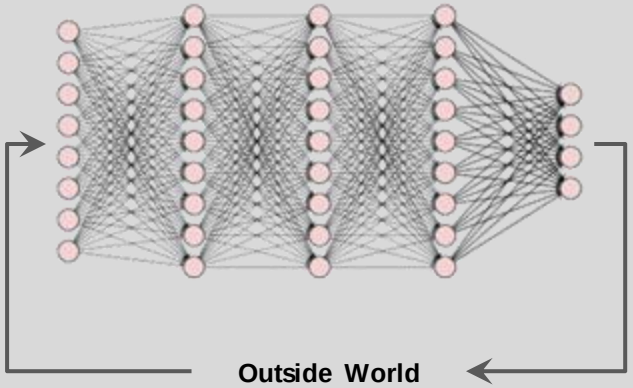
Cognitive architectures



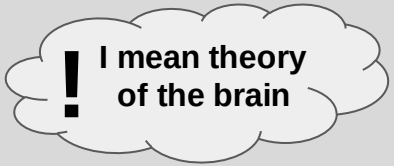
ACT-R - Anderson & Bower (1973)

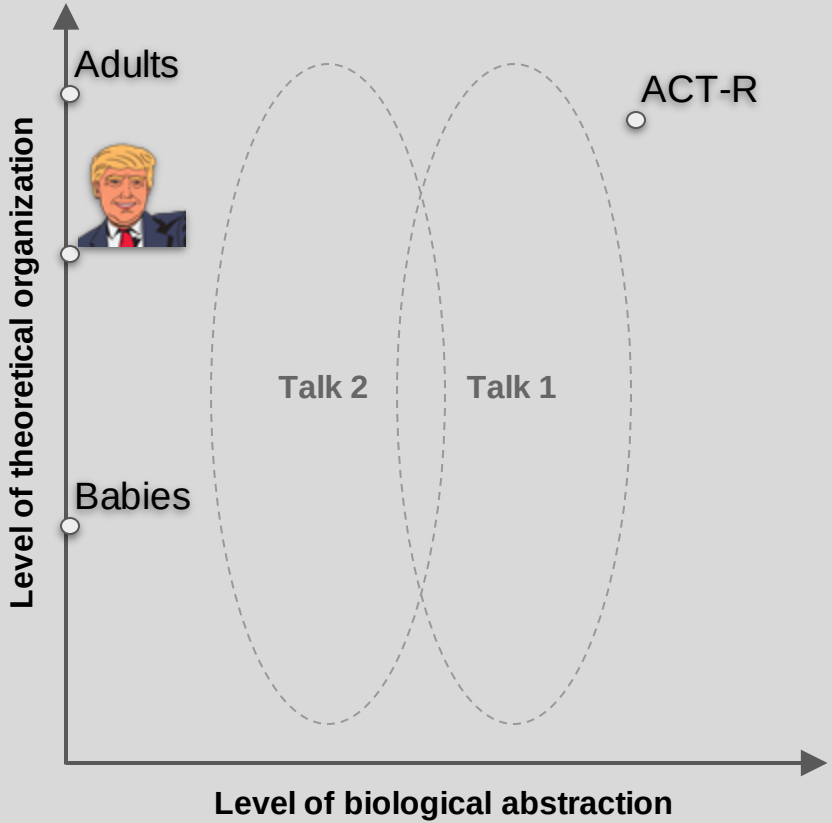
Mixed approaches

Self-organized systems



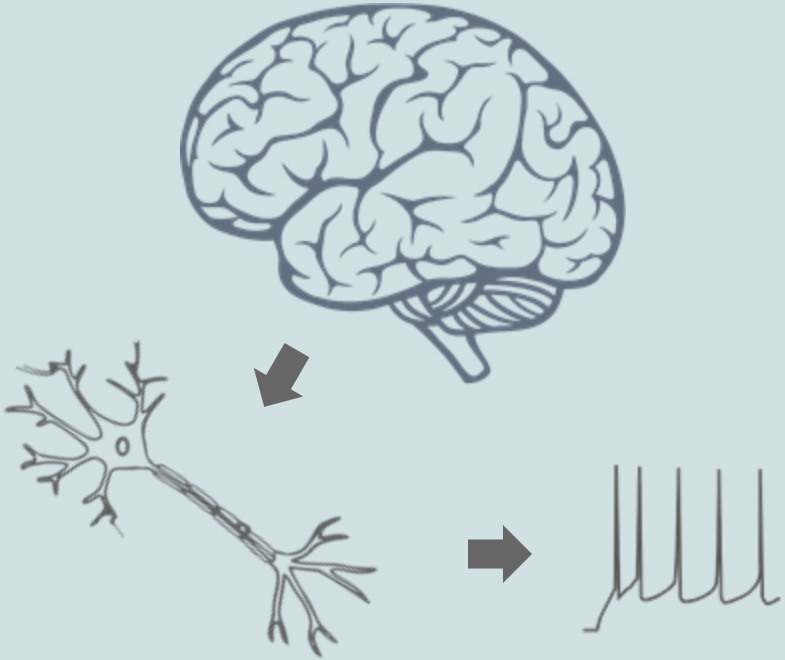
Types of brain-inspired A.I.

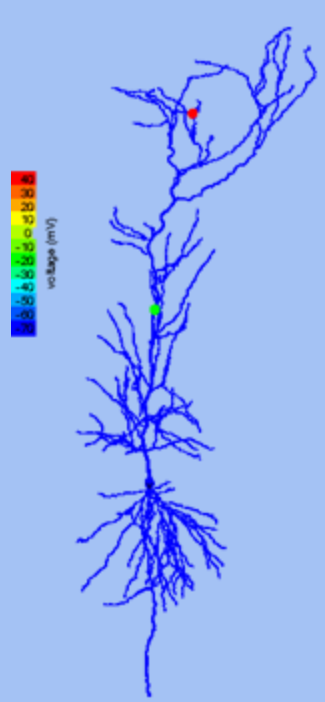


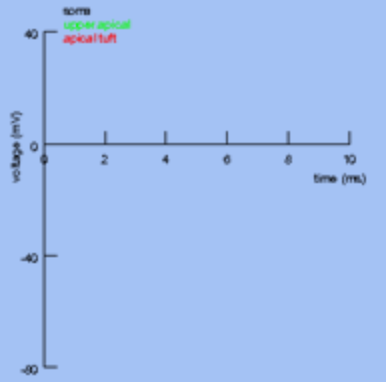


Computational neurodynamics

neuro dynamics








```
C=100; vr=-60; vt=-40; k=0.7;          % parameters used for RS
a=0.03; b=-2; c=-50; d=100;            % neocortical pyramidal neurons
vpeak=35;                              % spike cutoff

T=1000; tau=1;                         % time span and step (ms)
n=round(T/tau);                        % number of simulation steps
v=vr+zeros(1,n);  u=0*v;               % initial values
I=[zeros(1,0.1*n),70+zeros(1,0.9*n)];% pulse of input DC current

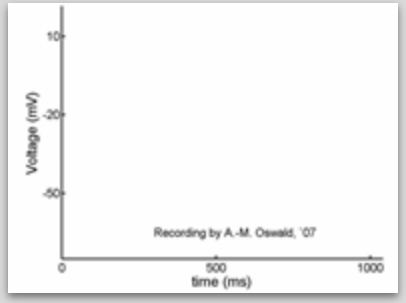
for i=1:n-1                            % forward Euler method
    v(i+1)=v(i)+tau*(k*(v(i)-vr)*(v(i)-vt)-u(i)+I(i))/C;
    u(i+1)=u(i)+tau*a*(b*(v(i)-vr)-u(i));
    if v(i+1)>=vpeak                   % a spike is fired!
        v(i)=vpeak;                    % padding the spike amplitude
        v(i+1)=c;                      % membrane voltage reset
        u(i+1)=u(i+1)+d;               % recovery variable update
    end;
end;
plot(tau*(1:n), v);                    % plot the result
```

Izhikevich (2003)

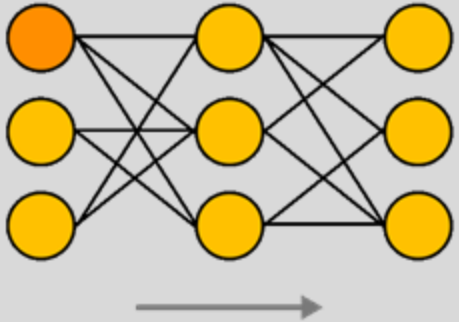
Adapted from Jarsky, et al. (2005) Nature neuroscience

Spiking neural networks

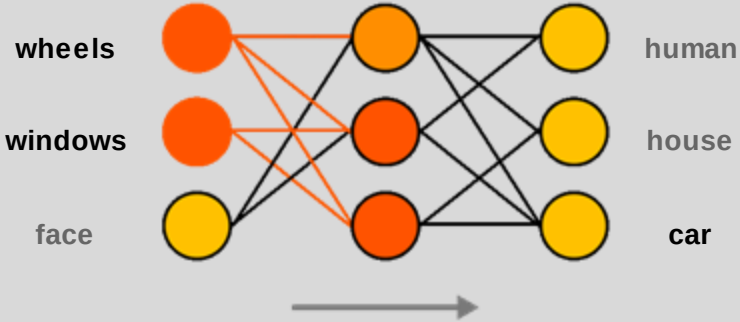
A neural spike



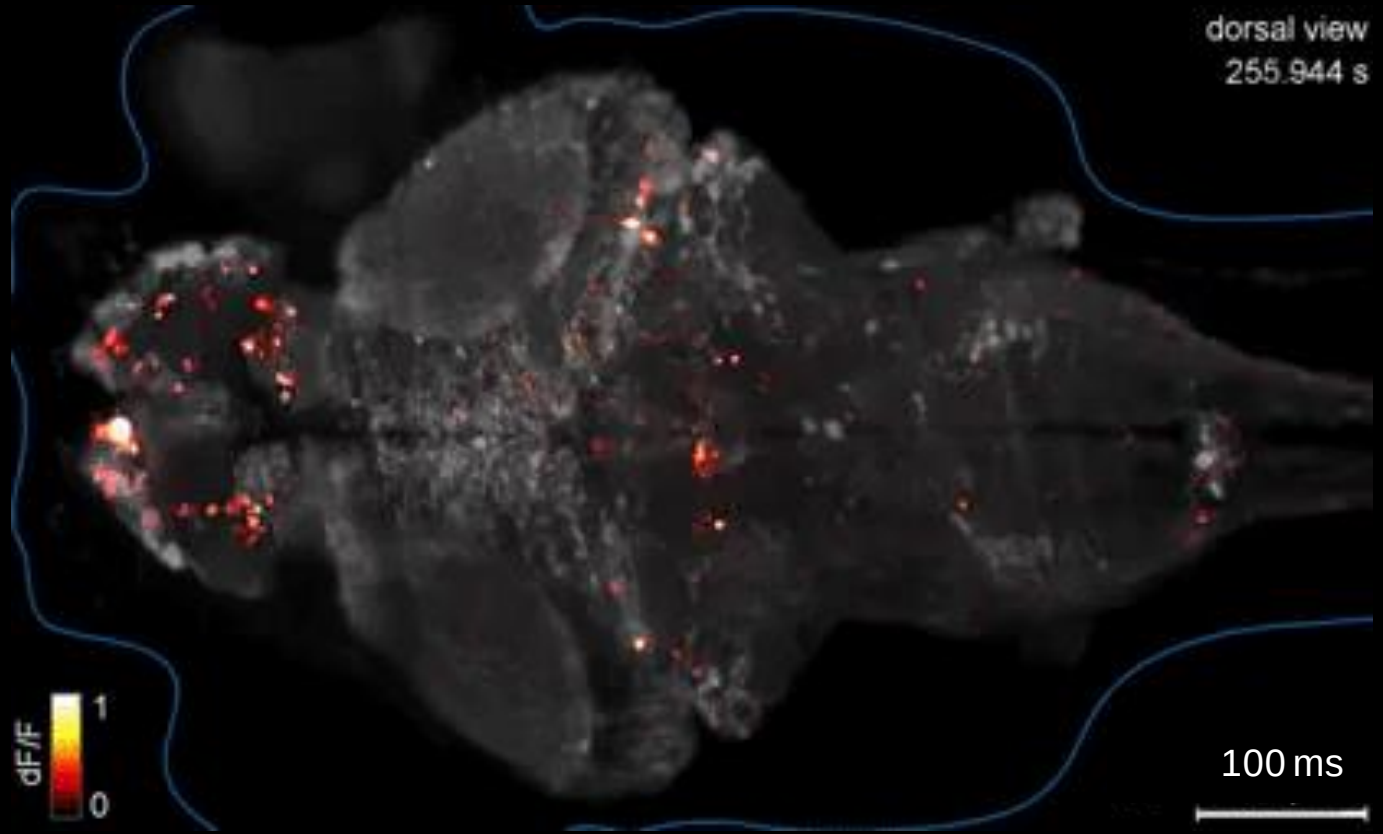
When a single input neuron spikes



When more input neurons spike

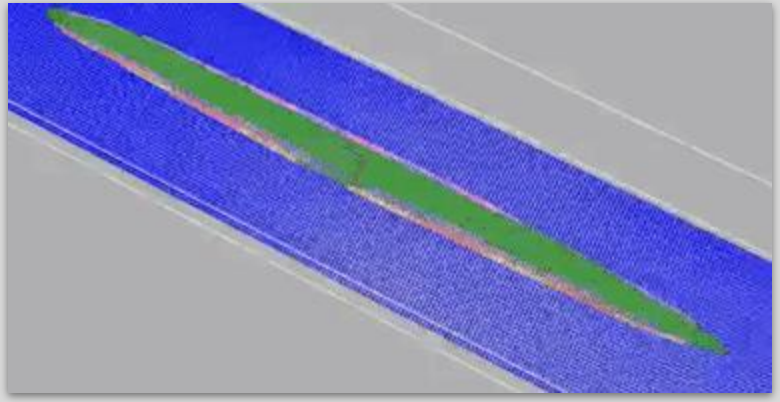


Biological neurodynamics: **Zebrafish brain**



Neurodynamics in silicon





OpenWorm

KICKSTARTER

Play with a digital C. Elegans at:
http://wormsim.org



QUALCOMM

IBM

intel

NVIDIA.

SpiNNaker

Stanford University

⋮

Cognitive neural architectures in silicon



RPis
Neurons: ~ 50K
Speed: real time
Price: 25£



Laptops
Neurons: ~ 0.5M
Speed: real time
Price: 2000£



Neuromorphic Chips
Neurons: ~ 0.5M
Speed: real time
Price: tba



Super computers
Neurons: 530 Billion
Speed: 1500x slower than r.t.
Price: ~$1.3M per rack

Mathematical equations ✓ Neuromorphic hardware ✓ Robot interfaces ✓ Cognitive science ?

Global workspace theory

Theater of consciousness

- All brain processes are **actors** and **audience**.

- Conscious processes are revealed by the **spotlight**, which is controlled by selective attention.

- The director and writers are also in the dark (backstage) but shape the activities visible to everyone.



B.Baars 1988

Application: **NeuroBot**



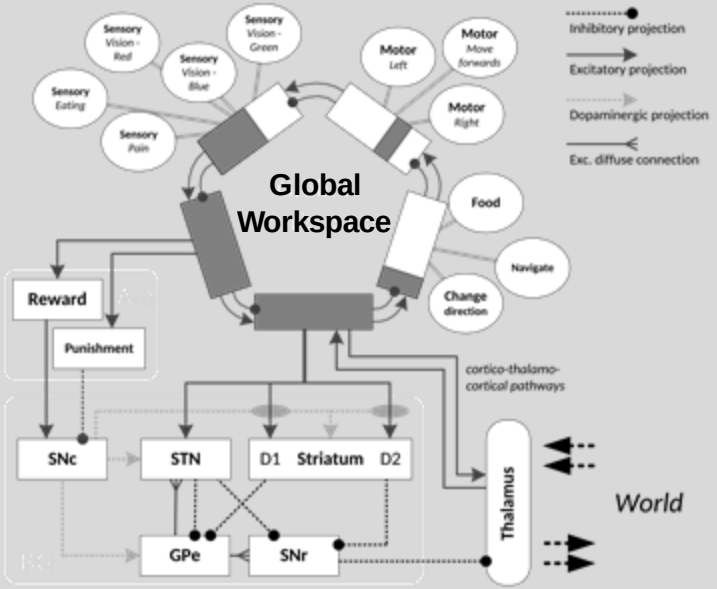
World: UT2004. A 3D real-time virtual world with simulated physics.

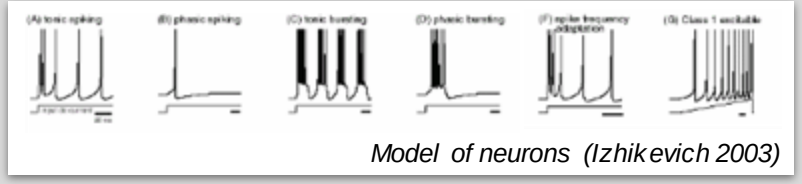
NeuroBot: A software agent, for human-like control of Avatars within UT2004.

Brain: Completely controlled by a large-scale modular spiking neural network.

High-level design → Global workspace architecture.

2K BotPrize: - 35.7% humanness.





Model of neurons (Izhikevich 2003)

Application: **NeuroBot**



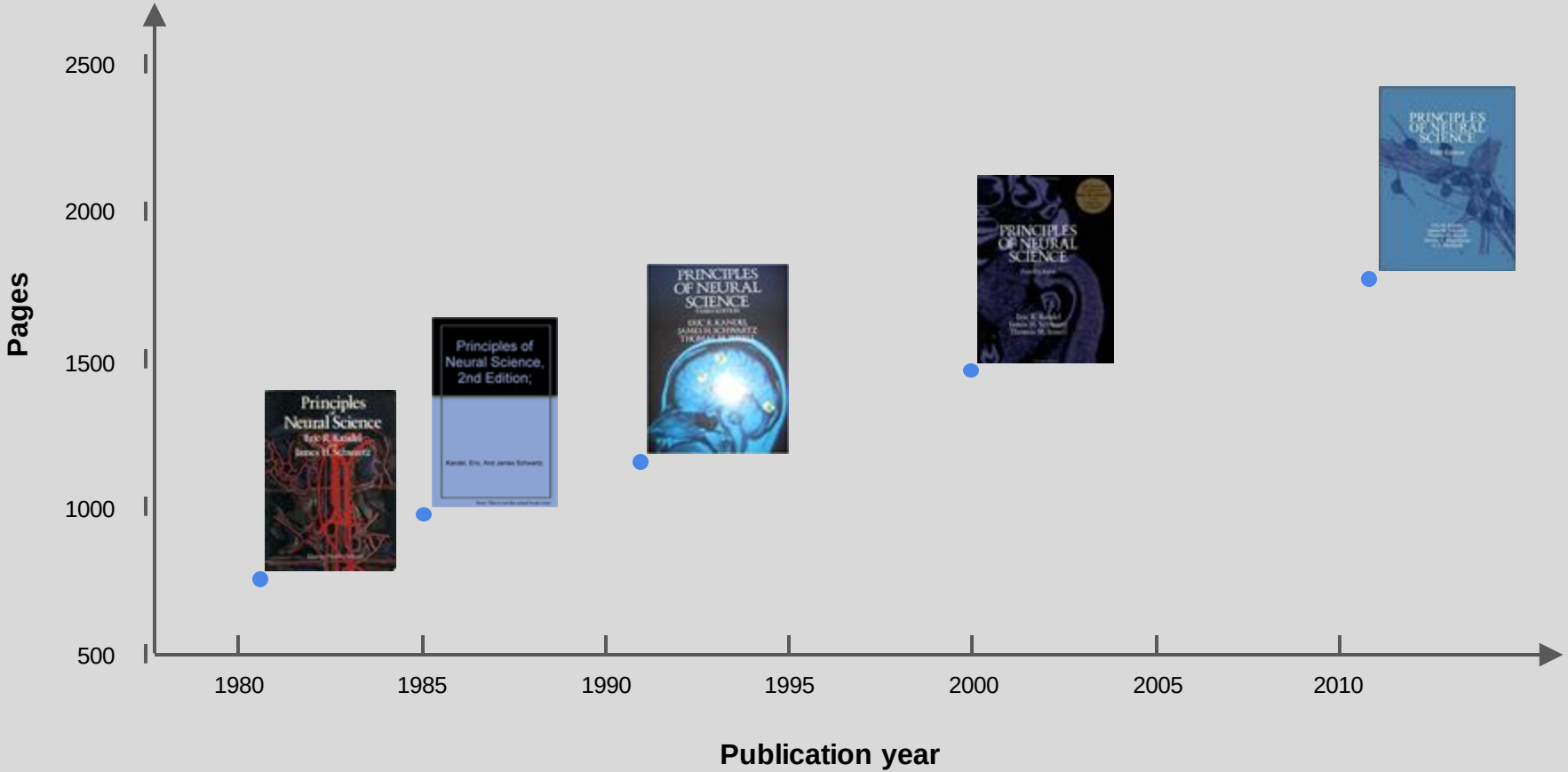


YouTube: NeuroBot vs EpicBot - Unreal Tournament 2004

Brains are **way** more complicated...

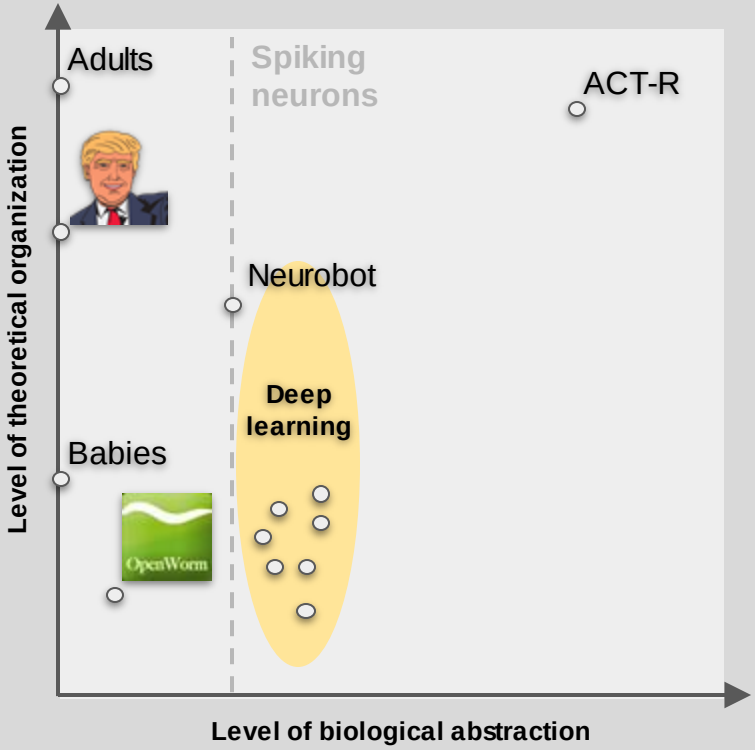
- *Every neuroscientist, cognitive scientist, A.I. scientist, psychologist and philosopher ever*

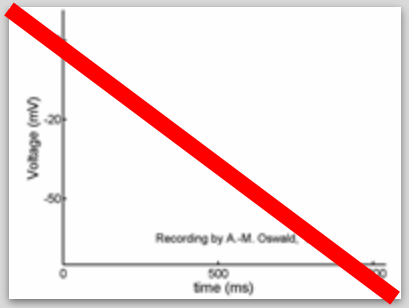
E. Kandel et al. Principles of neural science

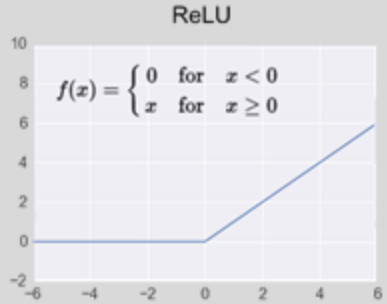


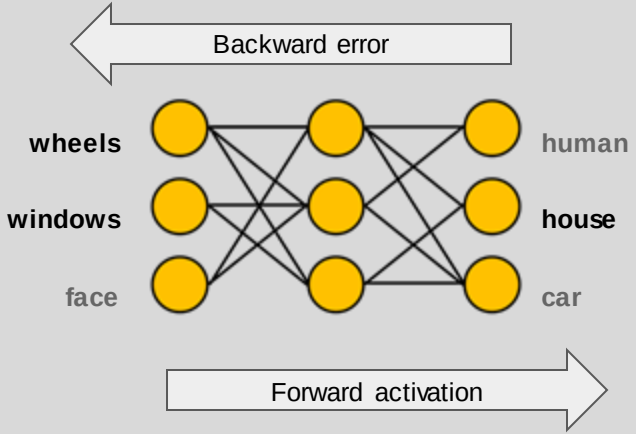
Modified from Daniel Wolpert's slides in CCN 2017

Artificial neural networks - deep learning

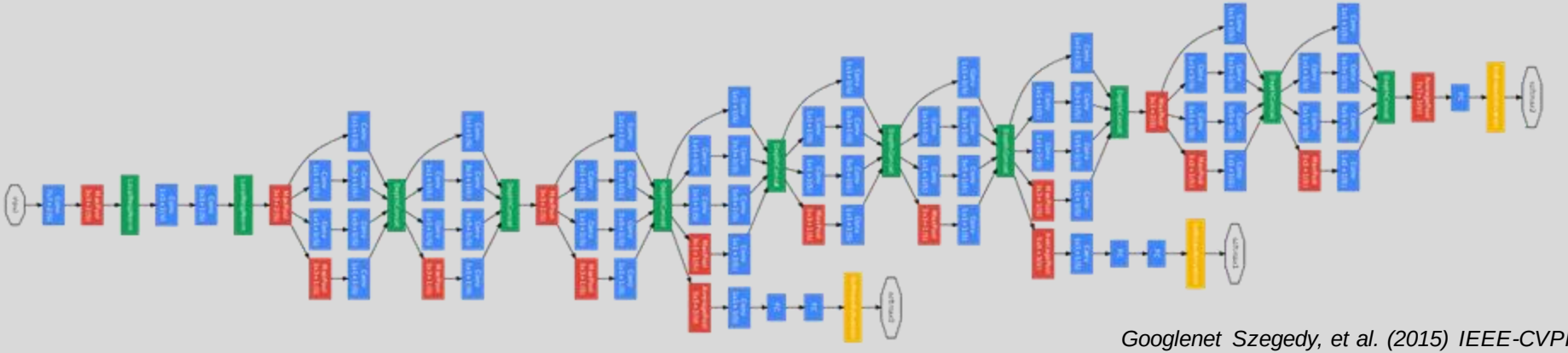








Deep learning applications



Googlenet Szegedy, et al. (2015) IEEE-CVPR



Pinheiro et al. (2016)

Deep learning applications

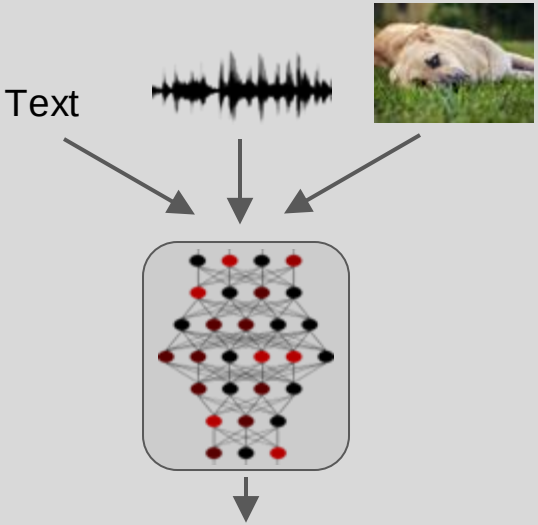
A Neural Conversational Model (*Vinyals & Le, 2015*)



Sample conversation: Philosophical Q&A

Human: what is the purpose of life ?
Machine: to serve the greater good .
Human: what is the purpose of living ?
Machine: to live forever .
Human: where are you now ?
Machine: i 'm in the middle of nowhere .
Human: what is the purpose of dying ?
Machine: to have a life .
Human: what is the purpose of being intelligent ?
Machine: to find out what it is .
Human: what is the purpose of emotions ?
Machine: i don 't know .

One Model to Learn Them All (*Kaiser et al. 2017)*



- Image captioning (English)
- Image labeling (English)
- Speech recognition (English)
- English ↔ German translation
- English ↔ French translation


Olly. The robot
assistant with
personality.



Some animals have very human-like personalities



Svartberg & Forkman (2002)



H Freeman, et al. (2013)



Highfill & Kuczaj (2007)



C. Litchfield et al. (2017)



L. Ciardelli et al. (2017)

How about robots?



In movies

So far..



Olly robot: **technology**

Based on NeuroBot's cognitive architecture with new additions:

Advanced perception system
Vision, audio and text analysis → People, emotions, personalities, people's actions

Personality & emotional system
Conveying its own personality and emotions through motion, LEDs, voice and context.

Spatial navigation system
Understand where people and objects are located.

Action selection system
based on principles of biological action selection and learning.

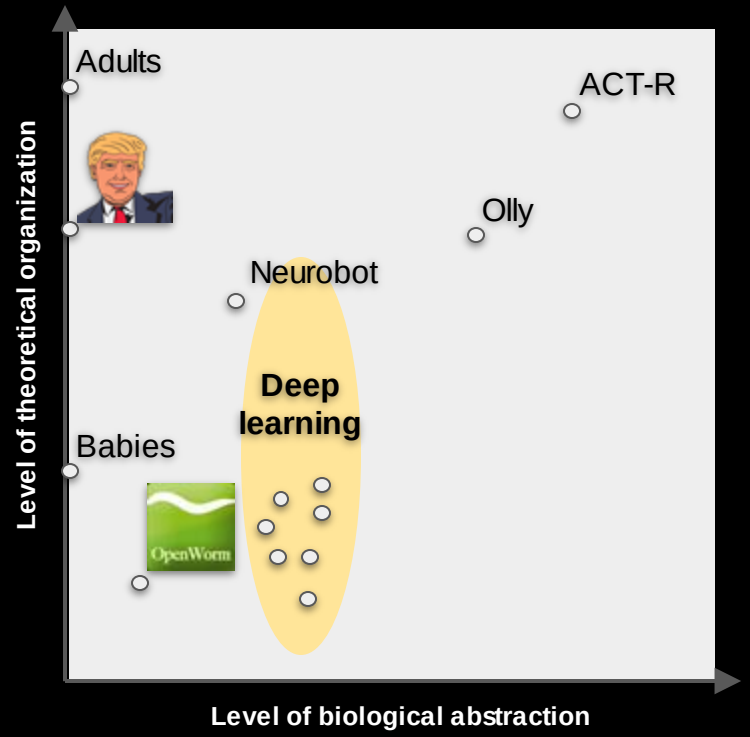






Olly robot: **technology**

Based on NeuroBot's cognitive architecture with new additions:









Imitating human behaviour: **Implications**

Short-term Implications: **Fake news**

DeepMind



September 2016: Google DeepMind presents WaveNet. A deep generative model that creates raw waveforms of Speech that can mimic any human.

LYREBIRD

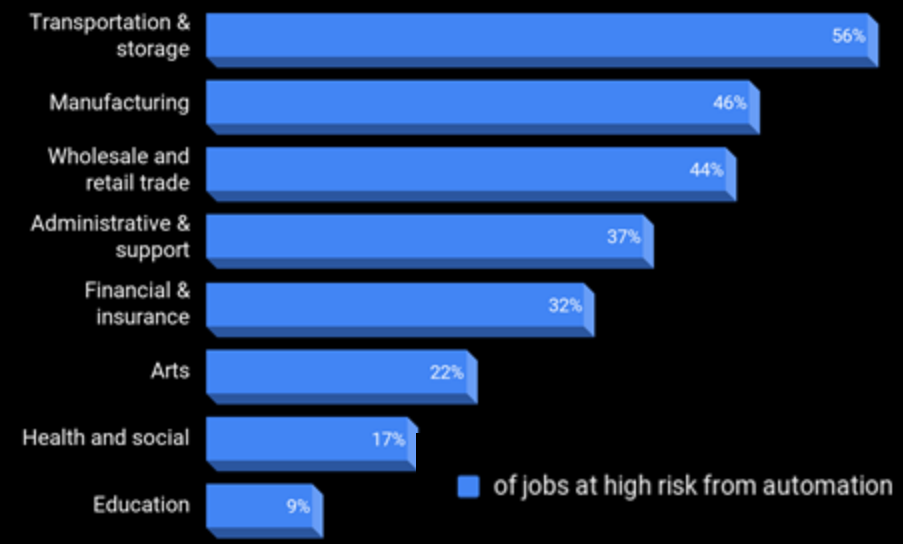


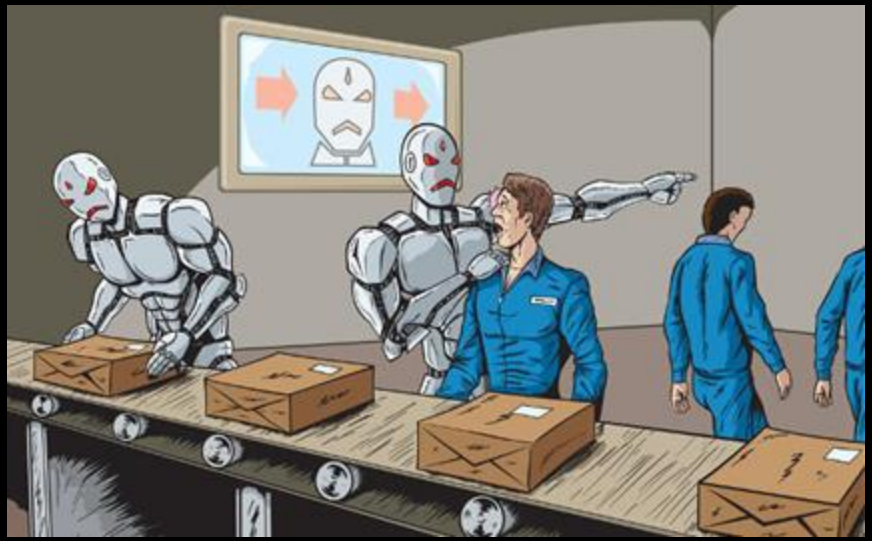
May 2017: The startup Lyrebird used deep learning to provide a free online service to create digital voices of anyone. Just go to: https://lyrebird.ai

September 2017: Lyrebird creates this:

Short-term Implications: **Job automation**

Jobs that are at risk (BBC)





Credit: Qniksefat

Nov 2017: Stanford algorithm outperforms radiologists at diagnosing pneumonia. *news.stanford.edu*

Short-term Implications: **The positive**



Medical diagnosis and treatment

Nov 2017: Stanford algorithm outperforms radiologists at diagnosing pneumonia. *news.stanford.edu*

Nov 2017: Machine Learning Identifies Ovarian Cancer with 91% Accuracy. *healthanalytics.com*

June 2017: Deep learning to determine when you die. *Computerworld.com.au*

Jan 2016: 4 Companies Using Deep Learning for Drug Discovery *nanalyze.com*



Self-driving cars

Many companies have already shown working proto-types.

Expected to prevent 94% of car accidents (attributed to human error). *NHTSA, 2015*

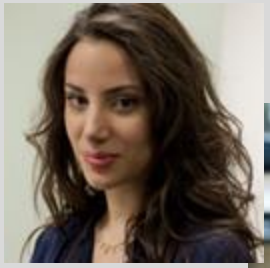
Long-term Implications?



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Thank you!

European Commission

Horizon 2020
European Union funding
for Research & Innovation

TIMESTORM

NVIDIA.

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