

Perspectives on AI

Inman Harvey

Classical AI

Origins



Methods

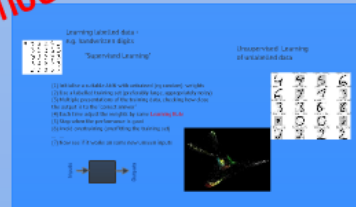


Neural Networks

Origins



Methods



Evolutionary Robotics

Origins



Methods



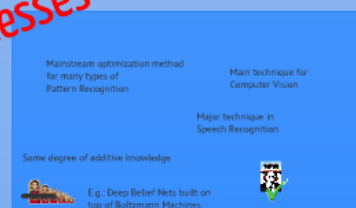
Successes



Failures



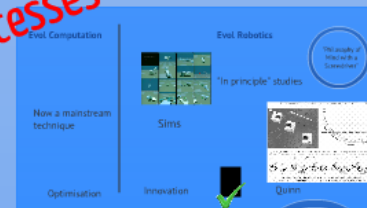
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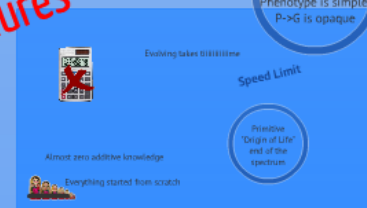
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Perspectives on AI



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Origins

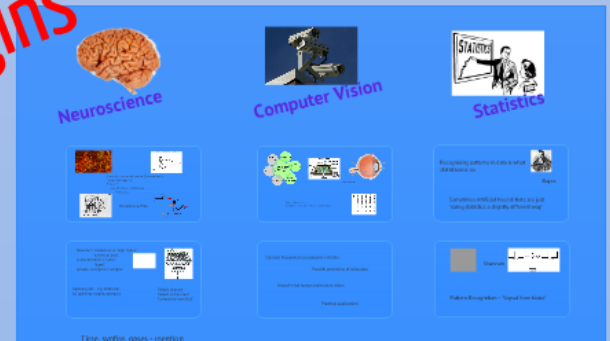


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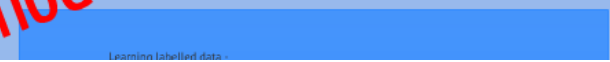


Neural Networks

Origins



Methods



SmartData

What kind of Data?

What kind of Smart?

"Knowing How" versus "Knowing That"

Context sensitivity

Perspectives on AI

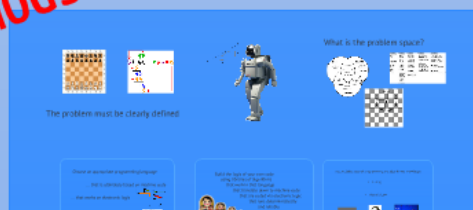
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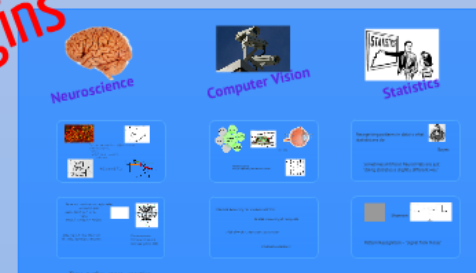


Methods

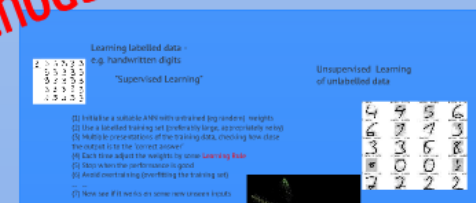


Neural Networks

Origins



Methods



Evo

Origins

Methods

Thought

differentiates
ns from other animals"

embodied Logic
y constrained worlds
no noise



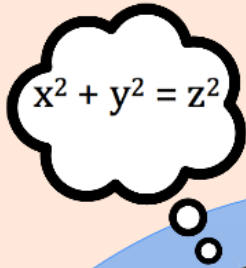
"AI always promises, never delivers"

Unfair !

Once delivered, ceases being called AI

Computer programming
Google
cell phones
... ..

Any sufficiently advanced technology is
indistinguishable from magic -- AC Clarke



Rational Thought

"What differentiates
Humans from other animals"

Disembodied Logic
Rigidly constrained worlds
Little/no noise
Chess



Adaptive Behaviour
Robust to changing context

4,000 kms each way
3 or 4 generations/cycle
Weighs a few milligrams
magnetic sense, sun compass
circadian clock, photoreceptors,
smell



"AI always prom

Once delivered

Any suff
indistin

Adaptive Behaviour

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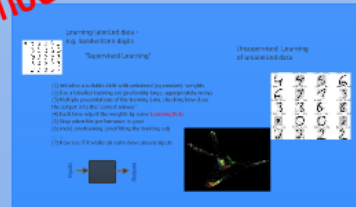


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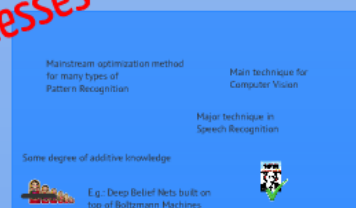
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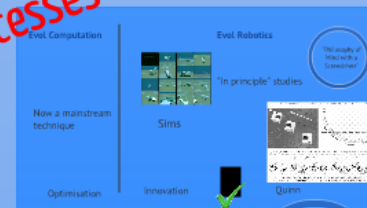
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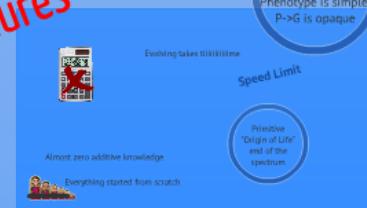
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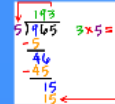
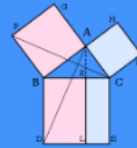
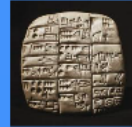


Classical AI

Origins



Pythagoras



Clerks - algorithms

Rational, disembodied thought

Written down - Permanent Record

Accounting, calculating

Deterministic, reproducible algorithms
- same results every time

Ideas can be separated from immediate context

Technology-driven, technology-driving

From Clay Tablets
to Printing Presses
to Steam Engines
to Electronics

Once written down, CDROM data is persistent

Substrate-neutral - clay/paper/silicon

Reasoning = Power

Man is a Rational Animal, and hence Superior

Intellectual problems more than adaptive skills

Chess, rather than riding a bicycle

... unless you can reduce riding a bike
to an intellectual problem

Church-Turing Thesis

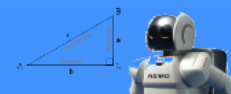
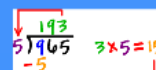
"Everything algorithmically computable is
computable by a Turing Machine"

[Informally: "computable" is a
technical vague, intuitive concept]

General Purpose Computing

The Human Brain is just another form of computer
with a different Operating System

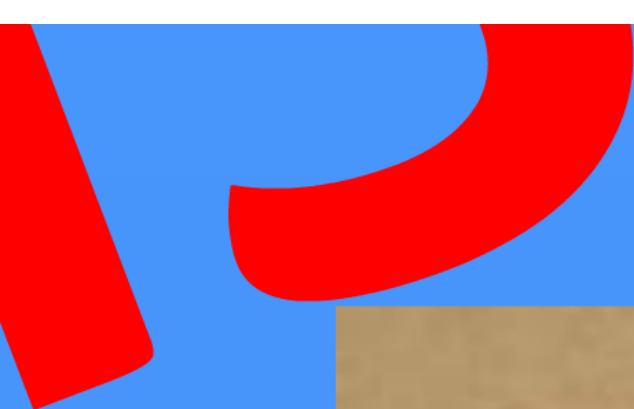
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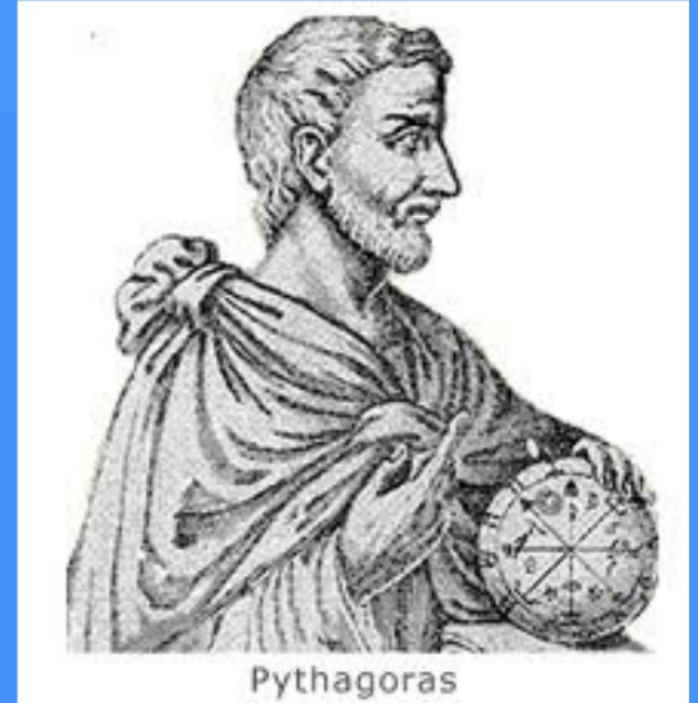


What is the problem space?

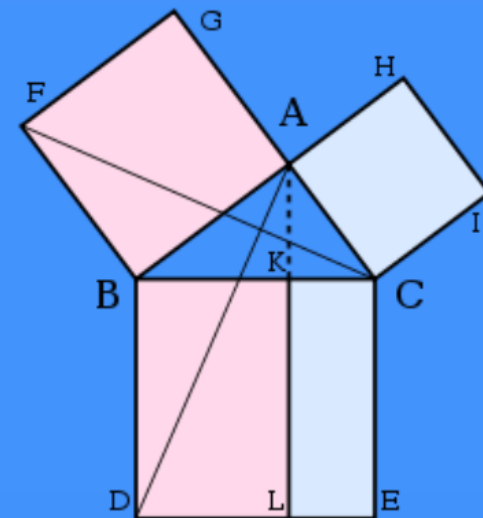
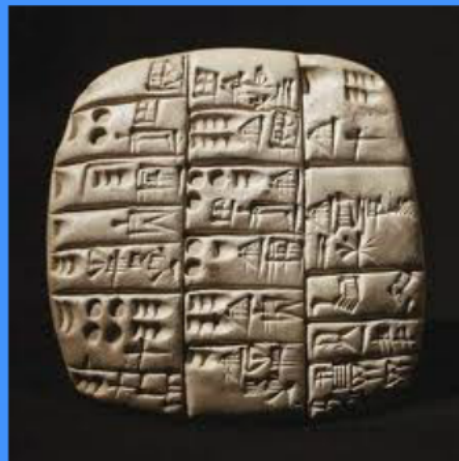


Problem	Solution	Problem	Solution	Problem	Solution
1. What is the problem?	1. What is the problem?	2. What is the problem?	2. What is the problem?	3. What is the problem?	3. What is the problem?
4. What is the problem?	4. What is the problem?	5. What is the problem?	5. What is the problem?	6. What is the problem?	6. What is the problem?
7. What is the problem?	7. What is the problem?	8. What is the problem?	8. What is the problem?	9. What is the problem?	9. What is the problem?
10. What is the problem?	10. What is the problem?	11. What is the problem?	11. What is the problem?	12. What is the problem?	12. What is the problem?

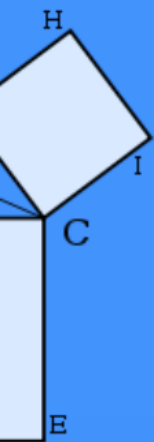
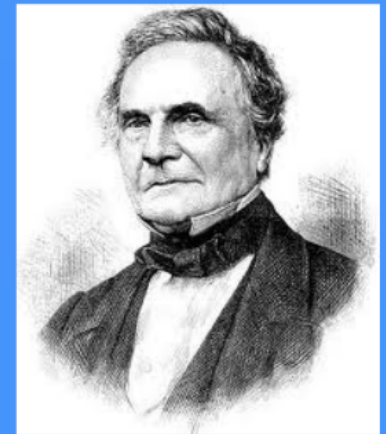




Pythagoras



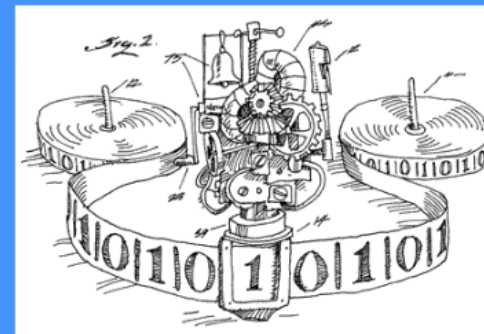




$$\begin{array}{r}
 193 \\
 5 \overline{) 965} \\
 \underline{-5} \\
 46 \\
 \underline{-45} \\
 15 \\
 15 \leftarrow
 \end{array}
 \quad
 3 \times 5 = 15$$







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Church-Turing Thesis



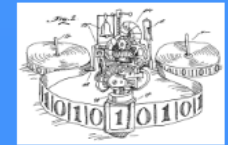
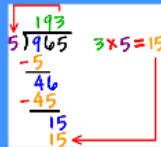
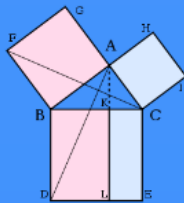
"Everything algorithmically computable is computable by a Turing Machine"

[unfortunately "computable" is a somewhat vague, intuitive concept!]

General Purpose Computing

The Human Brain is just another form of computer with a different Operating System

IS



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IS

Methods

Clerks - algorithms

Rational, Bookended Thought

Written down - Permanent Record

Accounting, calculating

Deterministic, reproducible algorithms
- same results every time

Ideas can be separated from immediate context

Technological drives technological thinking

From Clay Tablets
to Printing Press
to Steam Engines
to Computers

More vertical than horizontal, also vertical/horiz

Tabular nature -> spreadsheets

Reasoning = Power

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Church-Turing Thesis

"Everything algorithmically computable is computable by a Turing Machine"

(unlimited memory "tapes" is a mathematical, not a physical, ideal)

General Purpose Computing

"The Church-Turing Thesis is just another form of confusion with a different Denotating System"

The problem must be clearly defined

What is the problem space?

Choose an appropriate programming language

- ... that is ultimately based on machine code
- ... that works on electronic logic
- ... that is a fancy Turing machine

(clocked - analogue electronics -> digital)

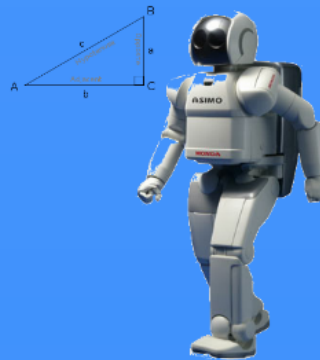
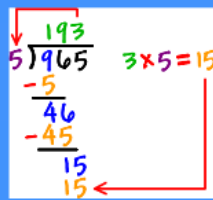
Build the logic of your own code using libraries of algorithms that work in that language that translate down to machine code that are coded via electronic logic that runs deterministically and reliably zillions of times

Accumulated body of programming and algorithmic knowledge

- Turing
- Moore's Law

ccos

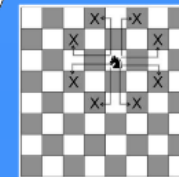
ods



What is the problem space?



1 letter PINK TEA	1 letter ALICE DRESS DREAM	1 letter BEACH CROQUET DREAM SAT ME WALSH	1 letter ADVENTURE AND-WINTER BUNCH-HAND	11 letters PINK FOOTMAN FROG FOOTMAN JAMES MONROE POOL OF TEARS
1 letter COOK	1 letter DODD DASH ROADS LOVE TALL	1 letter HAWK UNCOMMON TATTS	1 letter TREASURE THREE-SEE THUNDERBOLT THUNDERBOLT	12 letters FRIG OF HEARTS THUNDERBOLT THUNDERBOLT THUNDERBOLT
1 letter DASH DASH DASH DASH DASH	1 letter DASH DASH DASH DASH DASH	1 letter DASH DASH DASH DASH DASH	1 letter DASH DASH DASH DASH DASH	1 letter DASH DASH DASH DASH DASH



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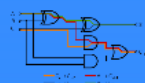
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Build the logic of your own code
using libraries of algorithms
that work in that language

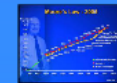
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Accumulated body of programming and algorithmic knowledge

+ Turing

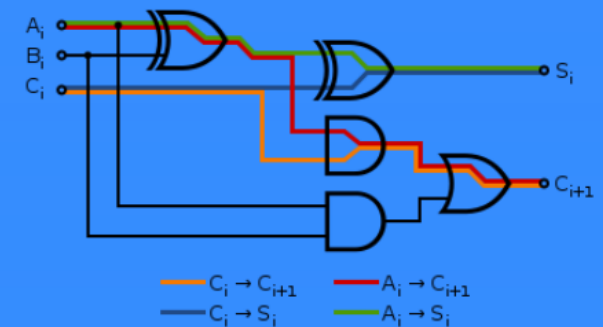
+ Moore's Law



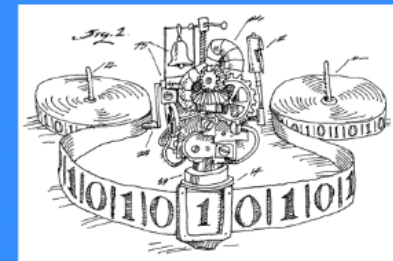
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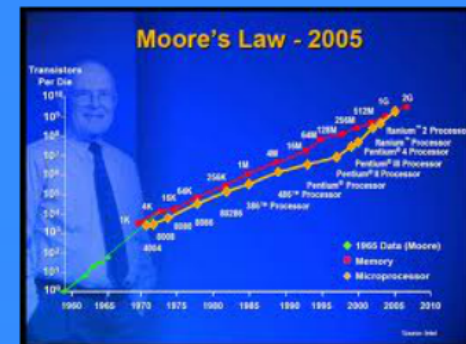
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Accumulated body of programming and algorithmic knowledge

+ Turing

+ Moore's Law



Watt's Law - 2000

The graph illustrates the projected increase in power consumption from 1990 to 2000. The Y-axis represents power in Watts (log scale, 10^0 to 10^4). The X-axis represents years (1990 to 2000). Three lines are plotted: 'Total Power' (red), 'Power per chip' (blue), and 'Power per transistor' (green). All three lines show a steep upward trend, indicating exponential growth in power consumption.

Methods





The problem must be clearly defined




What is the problem space?

Choose an appropriate programming language

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(Analog - analogue electronics - digital)

Build the logic of your own code using libraries of algorithms that work in that language that translate closer to machine code that are closer to the electronic logic that runs deterministically and reliably millions of times



Acquired body of programming and algorithm knowledge

- ... Theory
- ... Practical





Successes

Wow!

Everything to do with computing was originally "AI"



Virtuous Circle

Strength in depth



Another answer from AI

- ... Neural Networks (Artificial Neural Networks) ... are in fact in (at least) analogy with using the brain of Classical AI

General Purpose Computing (the Church-Turing Thesis) with increasing generality and power



Programming

- ... Signal Words
- ... Primitives
- ... Phrases

Computational or algorithmic description

If this is a kind of programming or algorithmic description, then we can describe our brains as a kind of



Viggo!!
Immutability!!

Or maybe the human brain is just a rather better computer?

The Singularity



Meth

Succe

atures

atures

sses

Wow!

Everything to do
with computing
was originally "AI"

Programming

Digital Media

Internet

Phones

...

All other approaches to AI
... Neural Networks, Evolutionary Robotics ...
are in practice (almost always)
built using the tools of
Classical AI

'General Purpose Computing'
the Church-Turing Thesis
may imply they are equivalent
anyway ??

Computationalist approach to Cognition

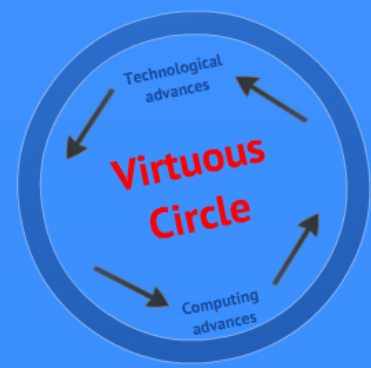
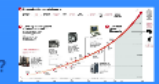
If this kind of reasoning is all there is to cognition,
then we can download our brains onto a chip!



Vippee!!
Immortality!!!

Or maybe the human brain is just a
rather inferior computer?

The Singularity?



Strength in depth



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Programming

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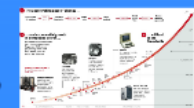
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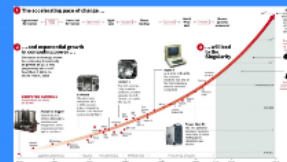
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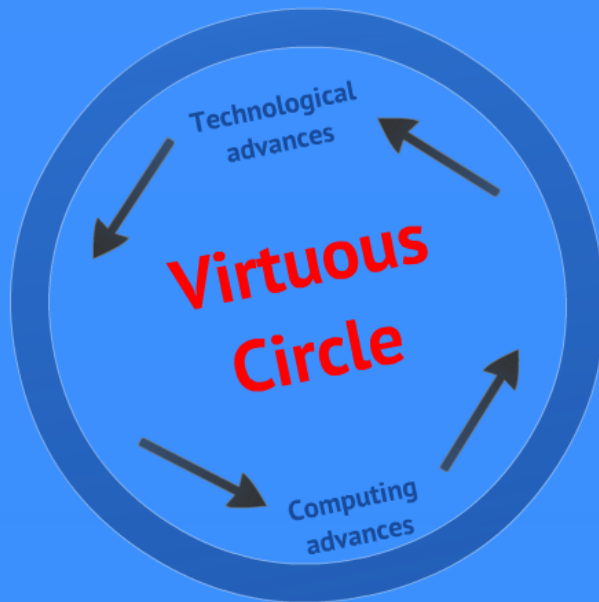


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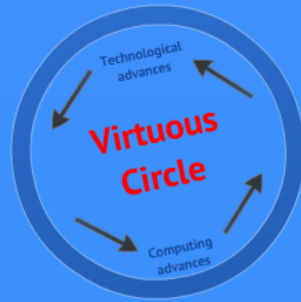


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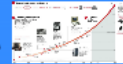
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Failures

The Frame Problem

What is the context?



How much is relevant?

What can I ignore?

Shakey the Robot



Dynamics ← series of Static snapshots

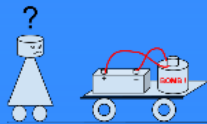
Brook's criticisms
Behavior-based robotics
Subsumption architecture



es

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Behavior-based robotics
Subsumption architecture



Ignored or Forgot Evolution

3,800 million years of evolved
adaptive behaviour
Only ~0.1 million years
of language and reasoning



Logic and reasoning is a specialised
niche form of adaptive behaviour

NOT

adaptive behaviour is a specialised
application of logical reasoning



Confusing the Map with the Territory

Working with maps
is working with Descriptions
- 'Knowing That'



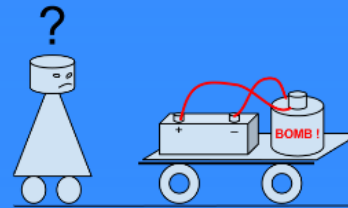
Ceci n'est pas une pipe.



GOFAI !

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What can I ignore?

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Confus

Working
is worki
- 'Know



ution



Optimative behaviour is a specialised application of logical reasoning

- Brook's criticisms
 - Behavior-based robotics
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GOFAI !



Specialised
behaviour
Specialised
reasoning

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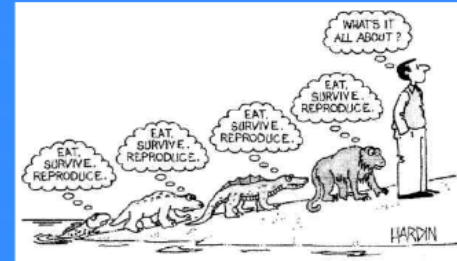


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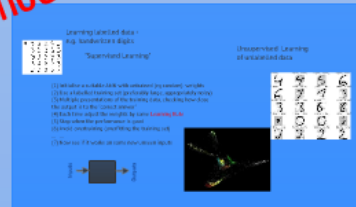


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Evolutionary Robotics

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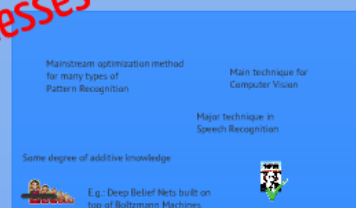
Successes



Failures



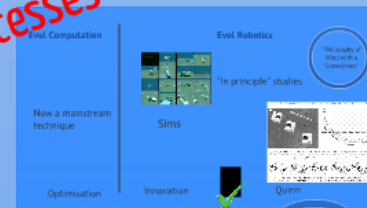
Successes



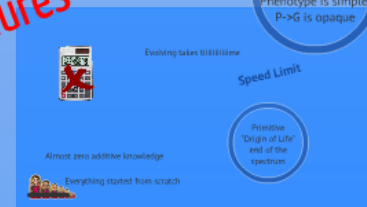
Failures



Successes



Failures



Neural Networks

Origins



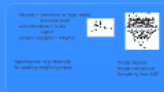
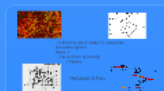
Neuroscience



Computer Vision



Statistics



Time, syntax, gases - mention

Methods

Learning labelled data -
e.g. handwritten digits

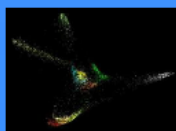
"Supervised Learning"



- (1) Initialise a suitable ANN with untrained (eg random) weights
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- (5) Stop when the performance is good
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- (7) Now see if it works on some new unseen inputs



Unsupervised Learning
of unlabelled data



Evolutionary

Origins



Darwinian Evolution

Reinforcement learning at the level of a population
Fitness (or death) the only training signal.
Tested for adaptivity for real in the real world



Heredity + Variation + Selection

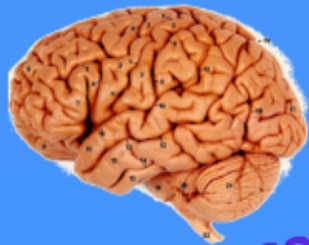
Methods

Genotype specifies
'brain' (and body?)
of an agent

Maybe genotype
specifies the parameters
to growth or development
of 'brain' (and body?)

Operational test of whole agent on

ms



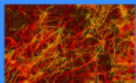
Neuroscience



Computer Vision



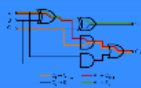
Statistics



The brain has lots of simple (?) components networked together.
Inputs →
Lots of neural 'processing'
→ Outputs



McCulloch & Pitts



Pattern Recognition
Using 3D input array → Reliable classification



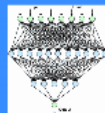
Recognising patterns in data is what statisticians do



Bayes

Sometimes Artificial Neural Nets are just 'doing statistics a slightly different way'

Neurons = 'transistors' or 'logic nodes'
'activation level'
axons/dendrites = 'wires'
'signal'
synaptic strengths = 'weights'



Updating rule - e.g. Hebb rule
for updating weights/synapses

'Simple neurons'
'Simple architecture'
'Complexity from SIZE'

Classical Reasoning has problems with this

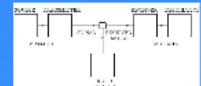
Parallel processing of noisy data

A lot of what human brains do is vision

Practical applications



Shannon



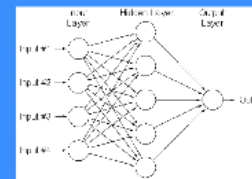
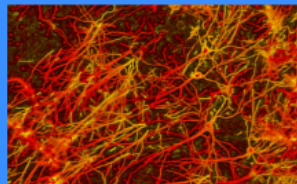
Pattern Recognition - 'Signal from Noise'

Time, synfire, gases - mention

dc

Neuroscience

Co

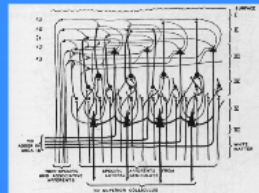


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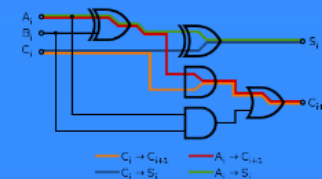
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McCulloch & Pitts



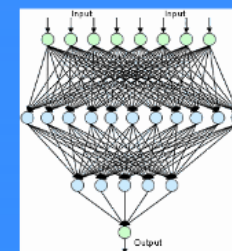
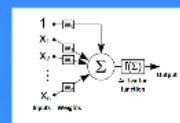
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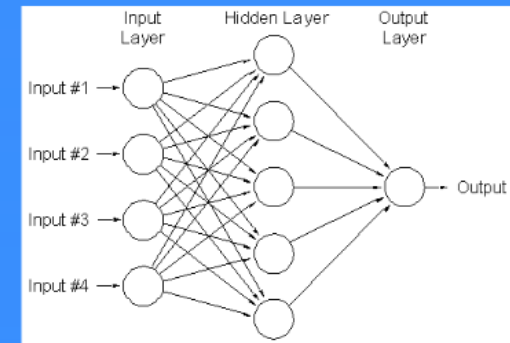
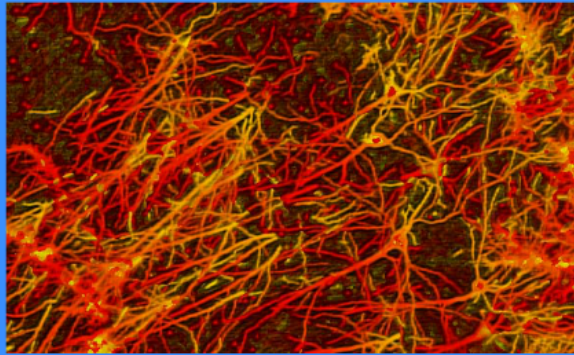
'signal'

synaptic strengths = 'weights'



Sign
Process
Physics
M

Class

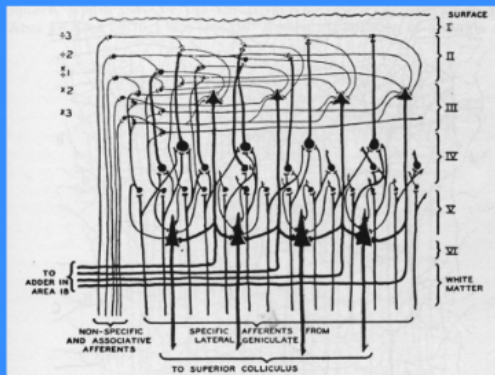


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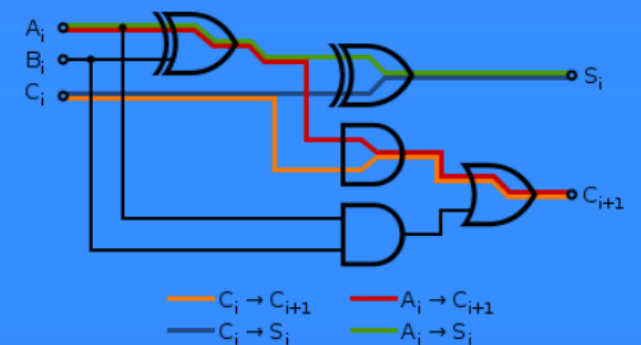
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McCulloch & Pitts



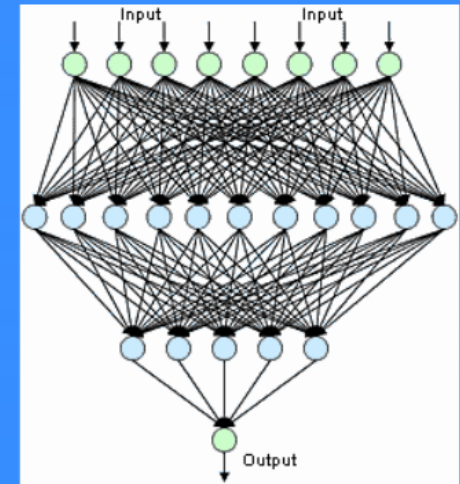
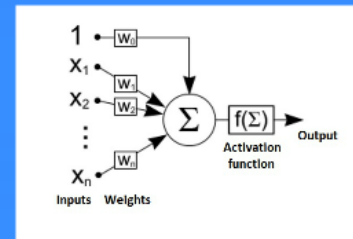
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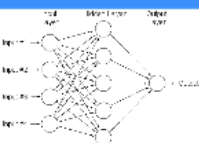
ce



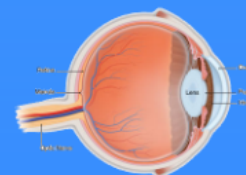
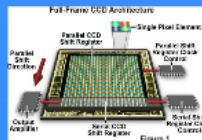
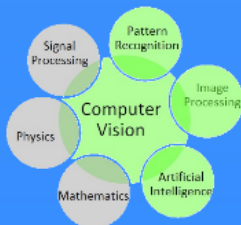
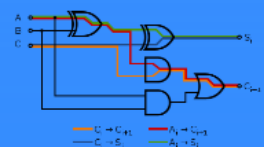
Computer Vision



S

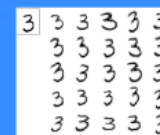


Components



CCD = Retina

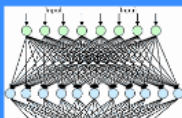
Pattern Recognition
Noisy 2D Input array -> Reliable classification

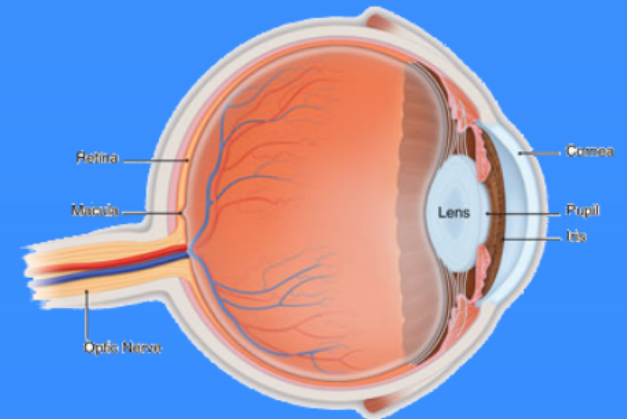
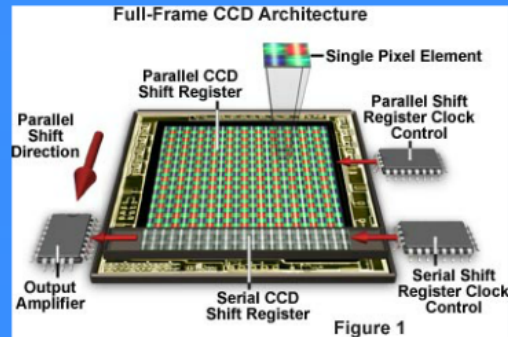
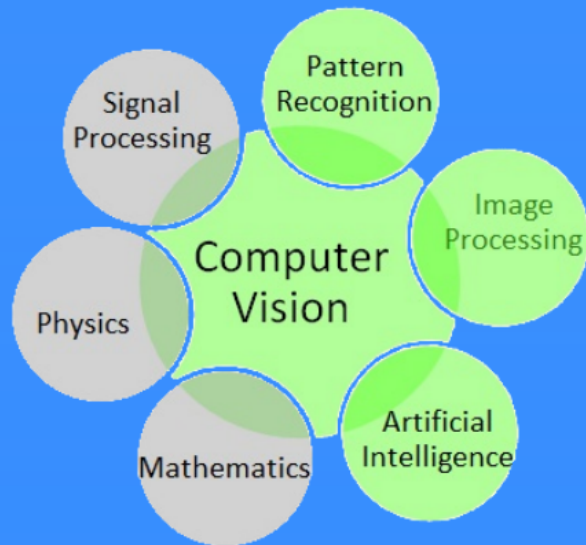


Recognising patterns
statisticians do

Sometimes A
'doing statist

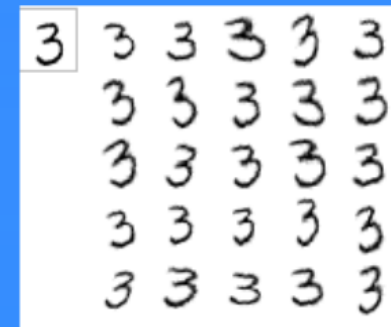
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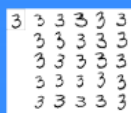


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Parallel processing of noisy data

A lot of what human brains do is vision

Practical applications



Parallel processing of noisy data

Practical applications



Bayes

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Shannon



Pattern Recognition ~ 'Signal from Noise'

Recognising patterns in data is what statisticians do

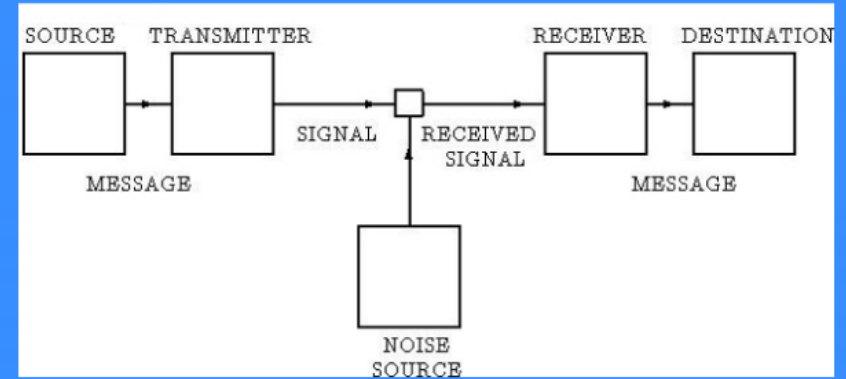


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Pattern Recognition ~ 'Signal from Noise'

Origins



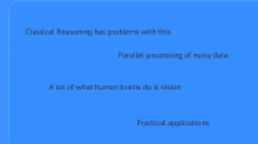
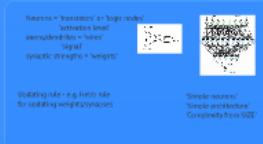
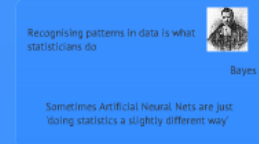
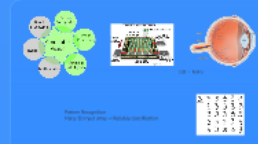
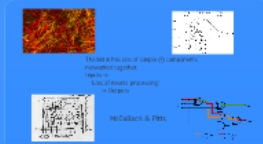
Neuroscience



Computer Vision



Statistics

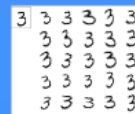


Time, synfire, gases - mention

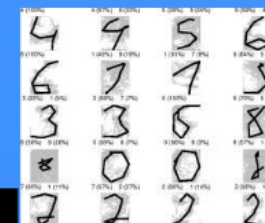
Methods

Learning labelled data -
e.g. handwritten digits

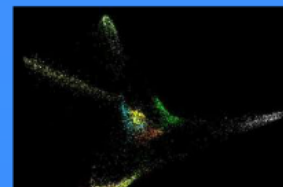
"Supervised Learning"



Unsupervised Learning
of unlabelled data

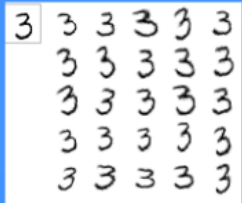


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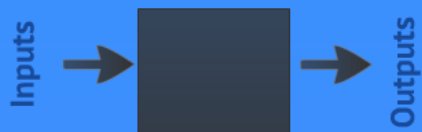


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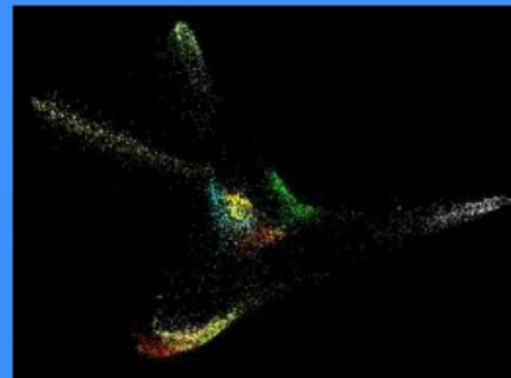
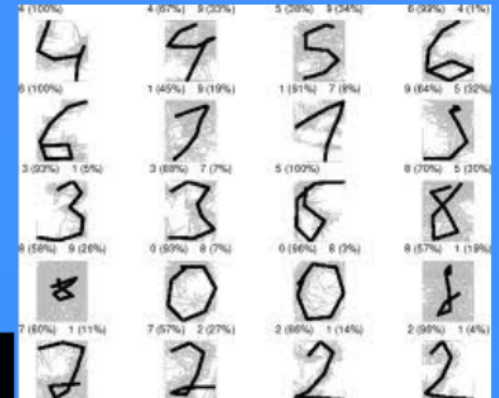
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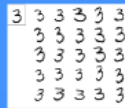
Unsupervised Learning
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Methods

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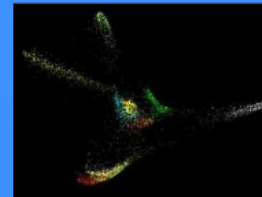
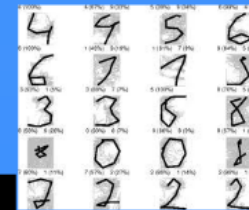
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Unsupervised Learning
of unlabelled data



Successes

Mainstream optimization method
for many types of
Pattern Recognition

Main technique for
Computer Vision

Major technique in
Speech Recognition

Some degree of additive knowledge

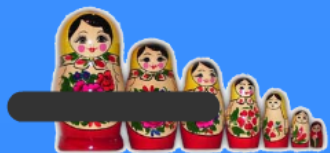
Issues

Mainstream optimization method
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Major technique in
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Some degree of additive knowledge

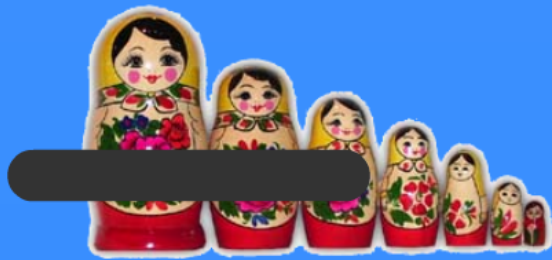


E.g.: Deep Belief Nets built on
top of Boltzmann Machines



Major
Speed

Some degree of additive knowledge



E.g.: Deep Belief Nets built on
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Success

Mainstream optimization method
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Pattern Recognition

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Major technique in
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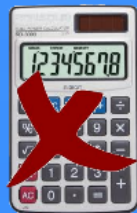
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E.g.: Deep Belief Nets built on
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Failures



Training takes tiiiiiiiiiiiiime

Typically does
not handle temporal
issues naturally -
usually has to cheat by
looking at successive

Relatively little additive knowledge

res



Training takes tiiiiiiiiiiiiiiiiime

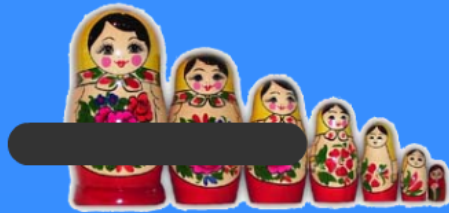
Relatively little additive knowledge



Typically does
not handle temporal
issues naturally -
usually has to cheat by
looking at successive
snapshots



Relatively little additive knowledge









The problem must be clearly defined

Choose an appropriate problem-solving strategy

- Make a drawing of known quantities, units
- Read words and think about the logic
- Work in a group, talking and listening




Be the boss of your own work

- Write the rules of discipline
- Read words and think about the logic
- Read words and think about the logic
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- Read words and think about the logic




Read words and think about the logic

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3 3 3 3 3
3 3 3 3 3
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"Supervised Learning"

unsupervised Learning
of unlabeled data

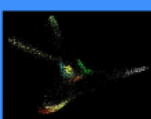
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Inputs



Outputs



Successes



Wow!

Everything to do with computing was originally "AI"

Playthings
Puzzle
Pipes

AI often represented as:
Puzzle Solving, Scheduling, Reasoning,
Learning, etc.
And many more...

General Purpose Computing
The Future: Being able
to do anything computers
can do.

Computer science is a discipline
in which we design, build, and
analyze systems that use
computers.

Strength in depth





Computer science is a discipline
in which we design, build, and
analyze systems that use
computers.

Strength in breadth



Successes

Essential

Mainstream optimization method
for many types of
Pattern Recognition

Main technique for
Computer Vision

Major technique in
Speech Recognition

Some degree of additive knowledge

E.g.: Deep Belief Nets built on
top of Boltzmann Machines

Failures

The Frame Problem

What is the context?

How much is relevant?

What can I ignore?

Shaky the Robot

Dynamics: series of static snapshots

Robot's internal state:
Beliefs, memory, intentions, and emotions

Ignored or Forget Evaluation

Continuous series of models
Each model is a snapshot of the world
Only 10-15 models can be stored
If knowledge isn't necessary

Logic programming is a representation of the world that is not a snapshot
Logic programming can't represent the continuous nature of logic programming

Enriching the Map with the Problem

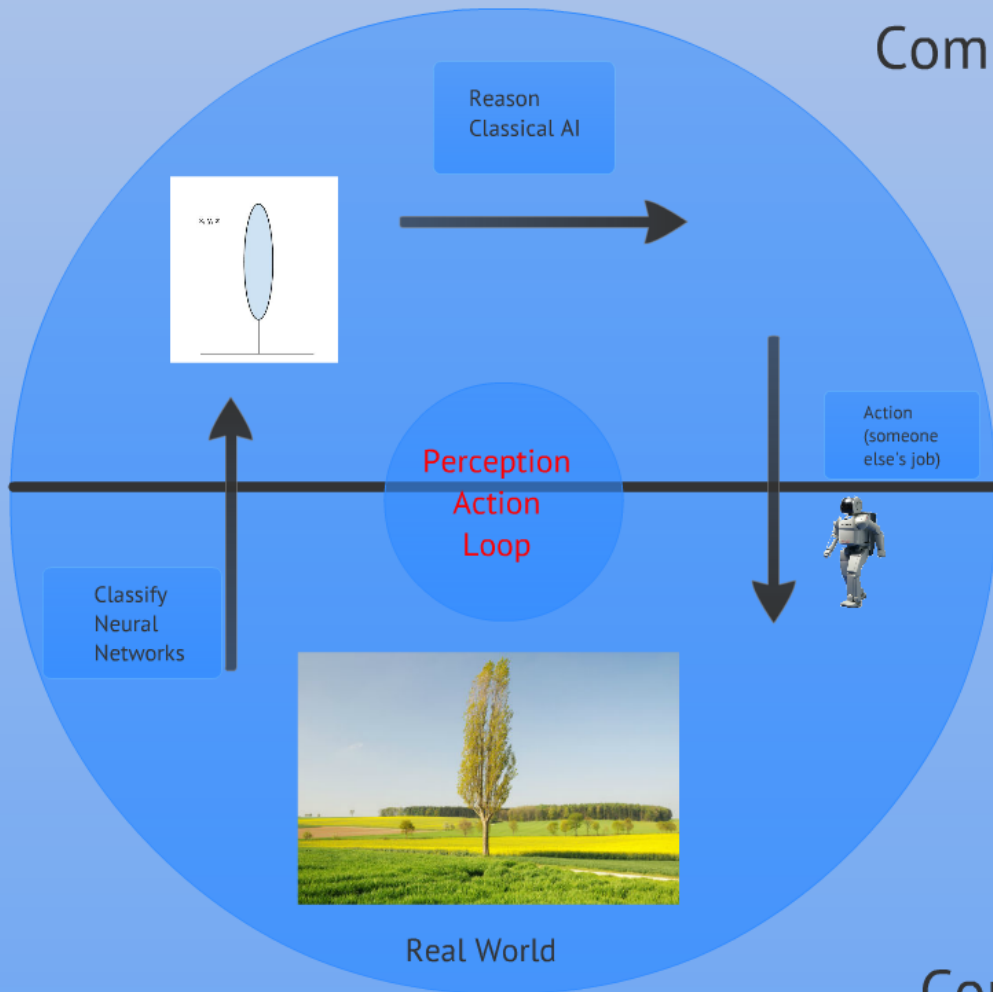
World is a 2D image
It needs to be a 3D image
To make it a 3D image, I need to know the location of the object

Failures

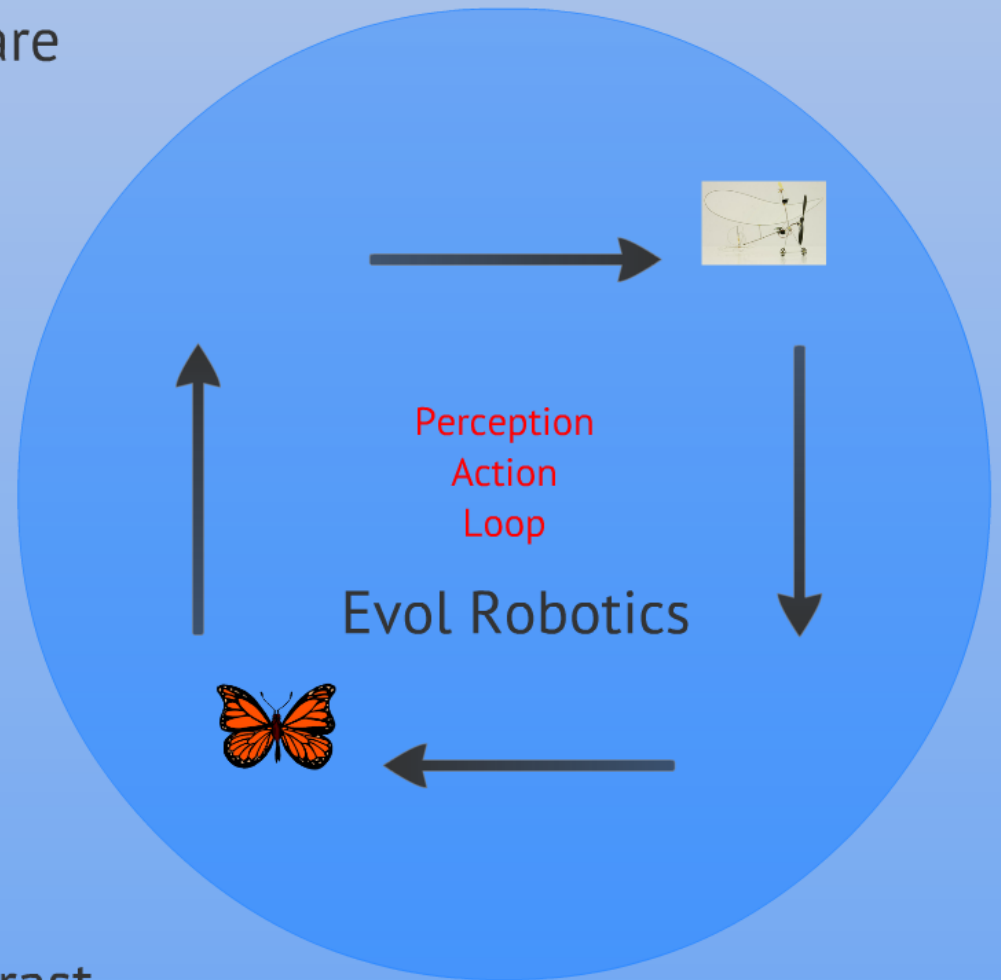
Pros

- Training takes time
- Typically does not handle temporal issues naturally - usually has to cheat by looking at successive snapshots
- Relatively little additive knowledge

Compare

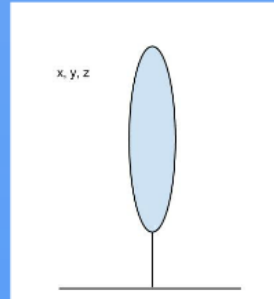


Contrast



Compare

Reason
Classical AI



Action
(someone
else's job)



Perception
Action
Loop

Classify
Neural
Networks



Real World

Contrast

Perspectives on AI

Inman Harvey

Classical AI

Origins



Methods

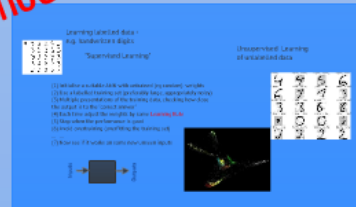


Neural Networks

Origins



Methods



Evolutionary Robotics

Origins



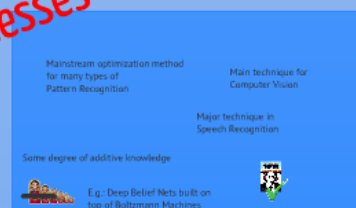
Methods



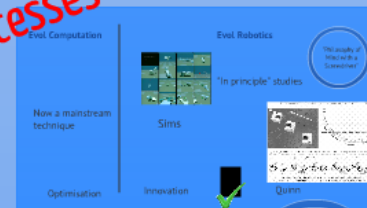
Successes



Successes



Successes



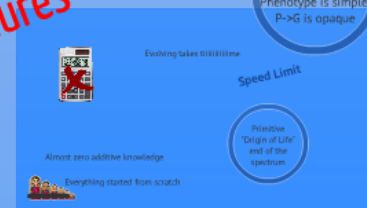
Failures



Failures



Failures



orks

Evolutionary Robotics

Origins



Darwinian Evolution

Reinforcement learning at the level of a population.
Fitness (or death) the only training signal.
Tested for adaptivity for real in the real world!



Heredity + Variation + Selection



Cybernetics

Control and Regulation in Animal and Machine

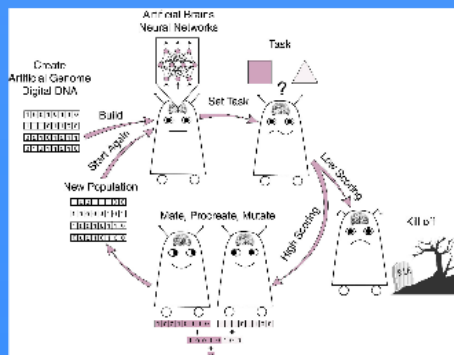


Dynamical System
approach to
Cognition

Methods

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'brain' (and body?)
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Maybe genotype
specifies the parameters
to growth or development
of 'brain' (and body?)

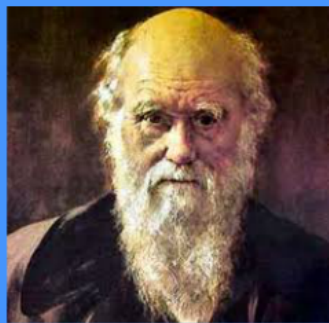


Operational test of whole agent over a 'lifetime' -> fitness

Reality/
Simulation



ms

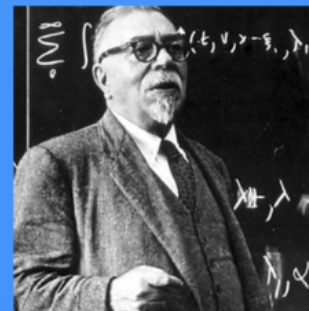


Darwinian Evolution

Reinforcement learning at the level of a population.
Fitness (or death) the only training signal.
Tested for adaptivity for real in the real world!



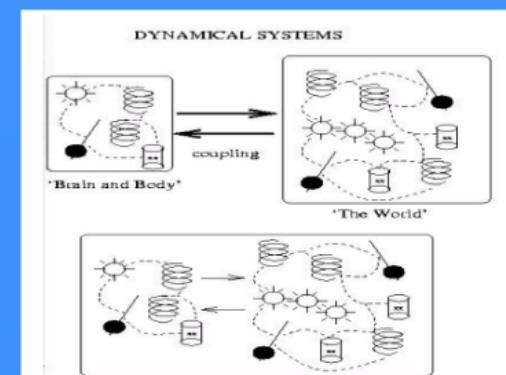
Heredity + Variation + Selection



Cybernetics

Control and Regulation in Animal and Machine

**Dynamical System
approach to
Cognition**

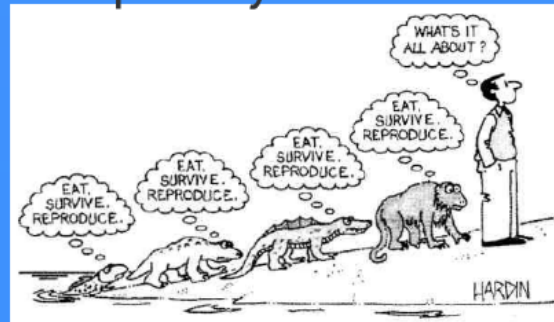


dc

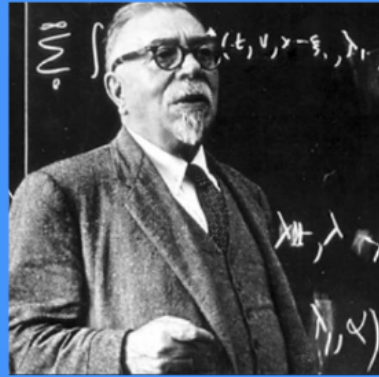


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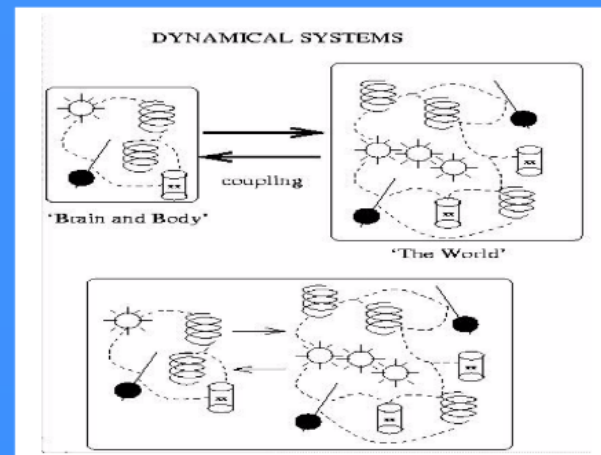
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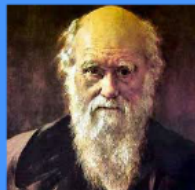
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Origins

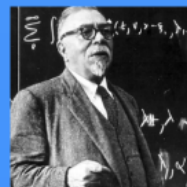


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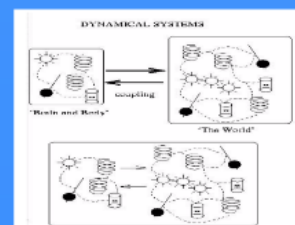
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Cybernetics

Control and Regulation in Animal and Machine

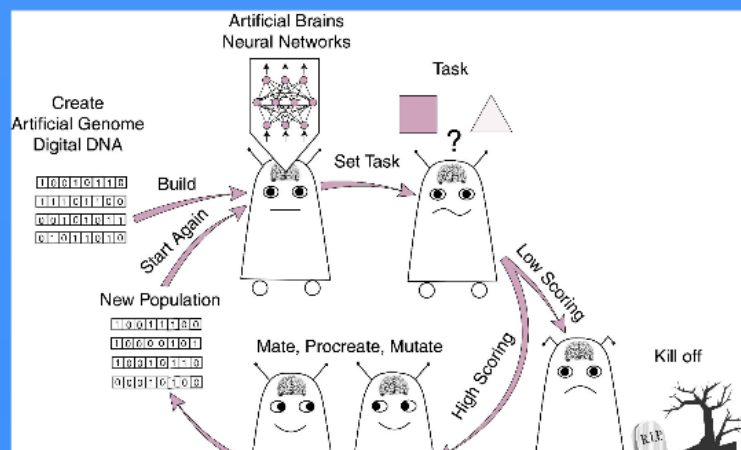
Dynamical System
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Methods

Genotype specifies
'brain' (and body?)
of an agent

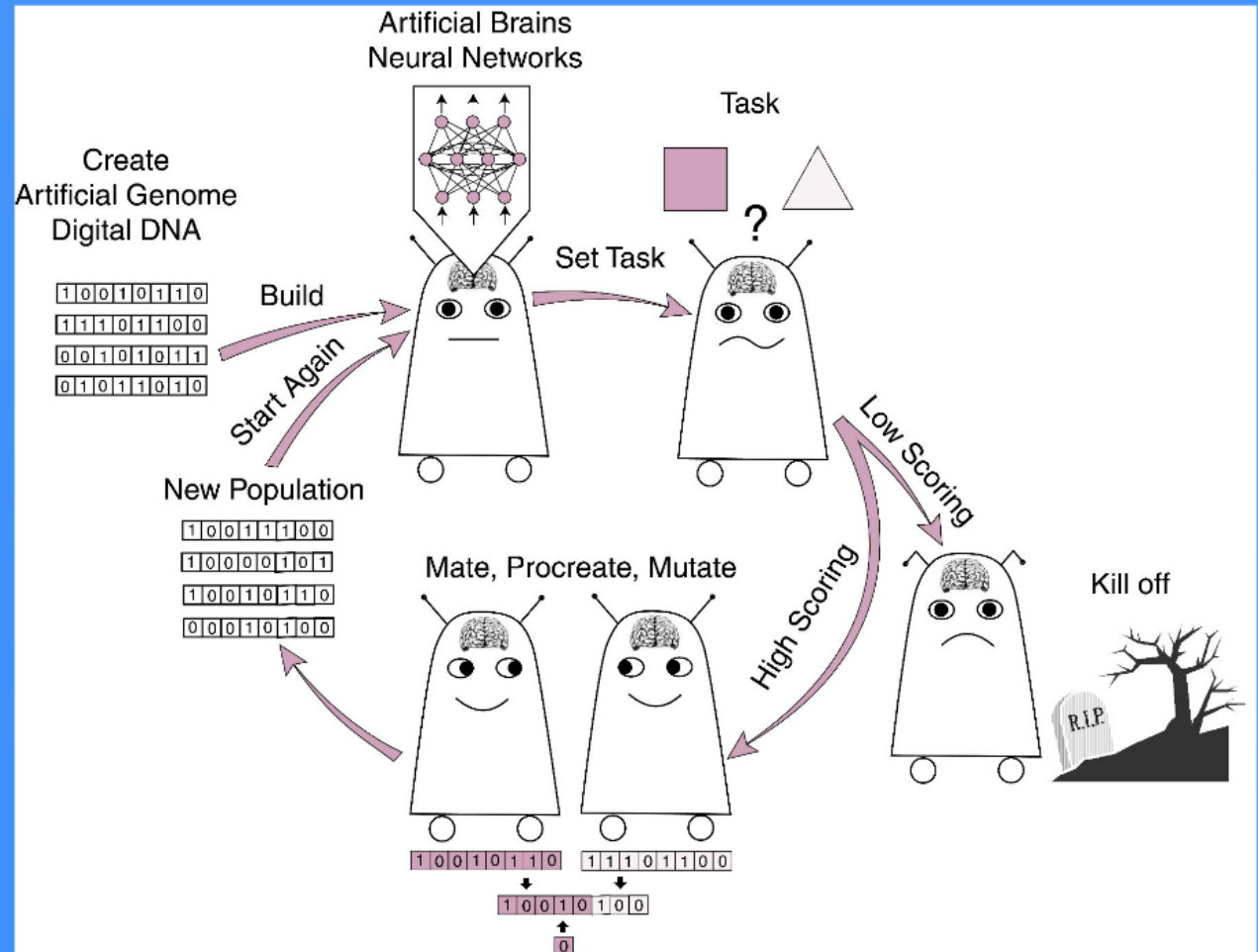
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Operational test of whole agent over a 'lifetime' -> fitness

Reality/
Simulation

Artificial Brains Neural Networks

Create
Artificial Genome
Digital DNA

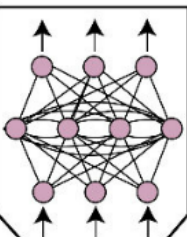
1	0	0	1	0	1	1	0
1	1	1	0	1	1	0	0
0	0	1	0	1	0	1	1
0	1	0	1	1	0	1	0

Build

Start Again

New Population

1	0	0	1	1	1	0	0
1	0	0	0	0	1	0	1
1	0	0	1	0	1	1	0
0	0	0	1	0	1	0	0



Set Task

Task



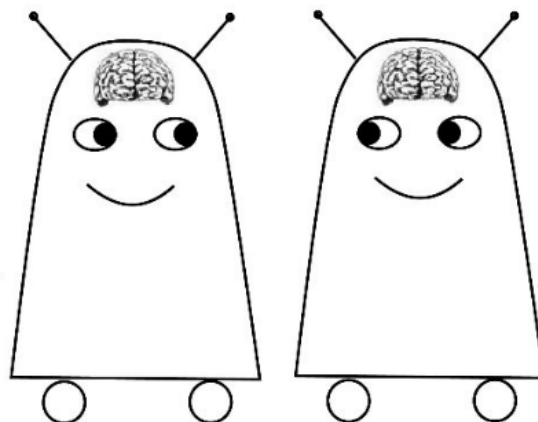
Low Scoring

Kill off



Mate, Procreate, Mutate

High Scoring

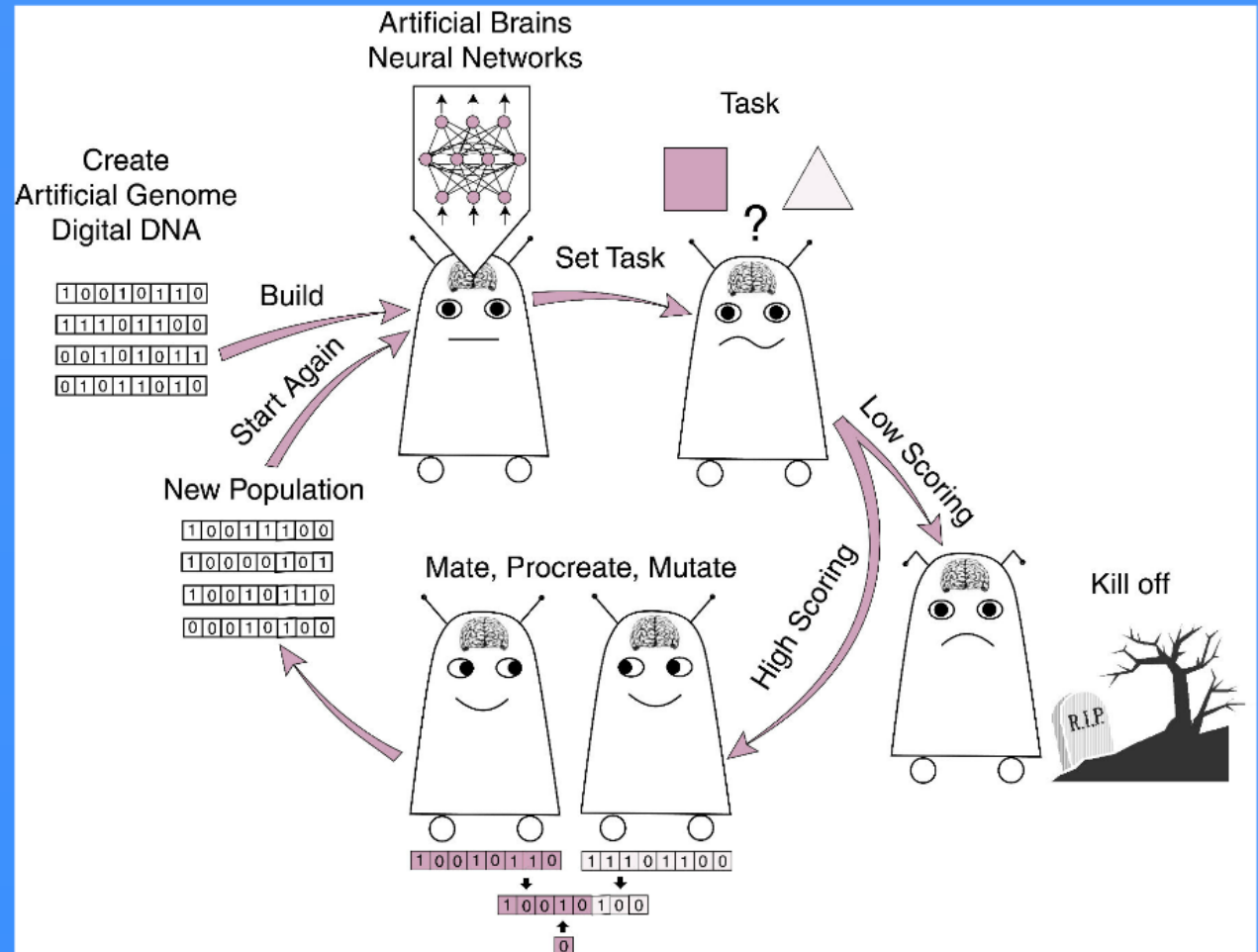


1	0	0	1	0	1	1	0
1	1	1	0	1	1	0	0
↓							
1	0	0	1	0	1	0	0
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0							

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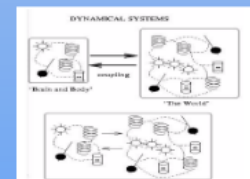
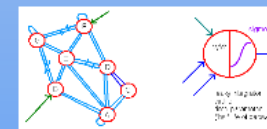


The Neural Networks evolved are typically rather than (timeless) information-filters

Real Time
Dynamical Systems

E.g. CTRNNs

$$\tau_i \frac{dy_i}{dt} = -y_i + \sum_{j=1}^n w_{ij} \sigma(y_j - \theta_j) + I_i(t)$$



Simulations

Problem of toy, unvalidated simulation

Envelope of Noise - evolve for more robustness than strictly need

Jakobi's Minimal Simulation approach:

Define Base set:
minimal env
features needed
for the job



Model these, with
appropriate env-
of-noise, to be
base-set-robust



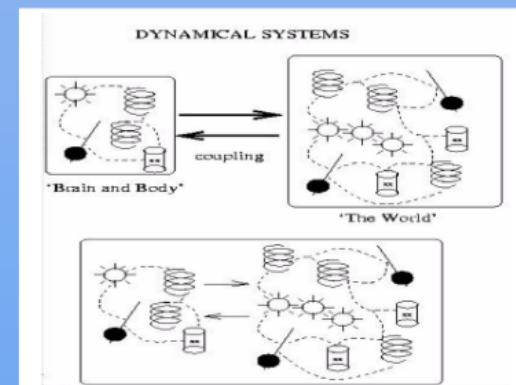
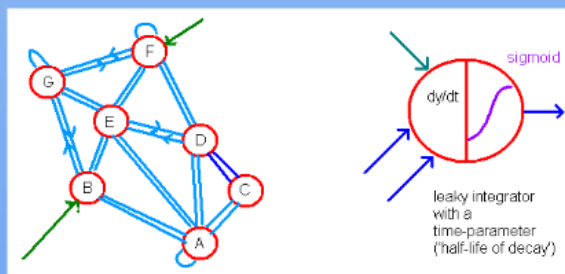
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ELSE with wild
unreliable noise!
base-set-exclusive

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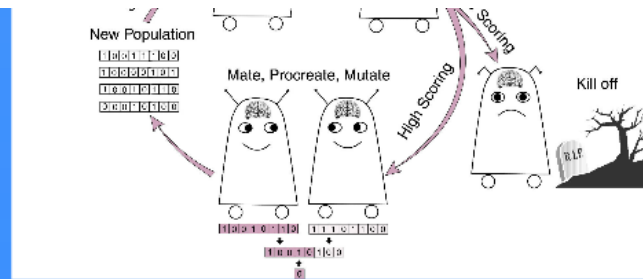


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Reality/
Simulation

Successes

Evol Computation

Now a mainstream technique

Optimisation

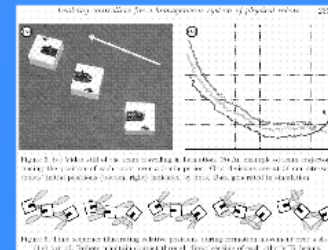
Evol Robotics

"In principle" studies

"Philosophy of
Mind with a
Screwdriver"



Sims



Quinn



Innovation

Opacity

Genotype ->
Phenotype is simple,
P->G is opaque

Failures

Lessons

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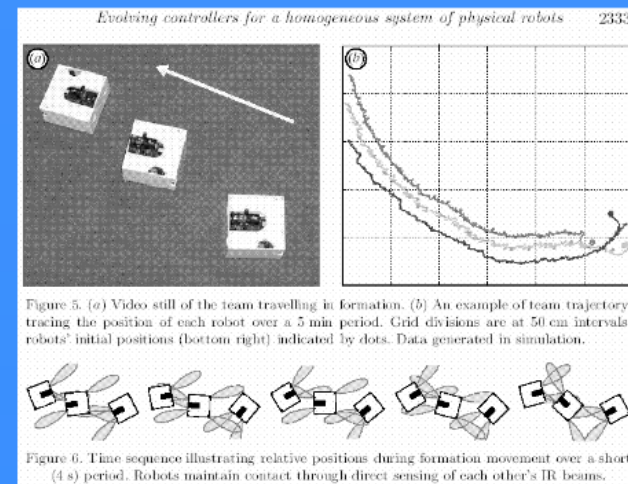
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on

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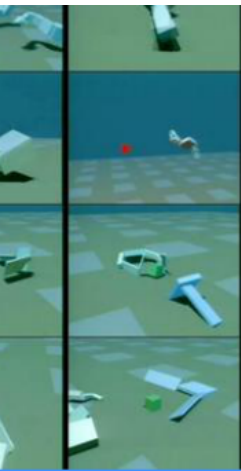


"In princip

ream

Sims

"In principle" studies



Evolving controllers for a homogeneous system of physical robots

2333

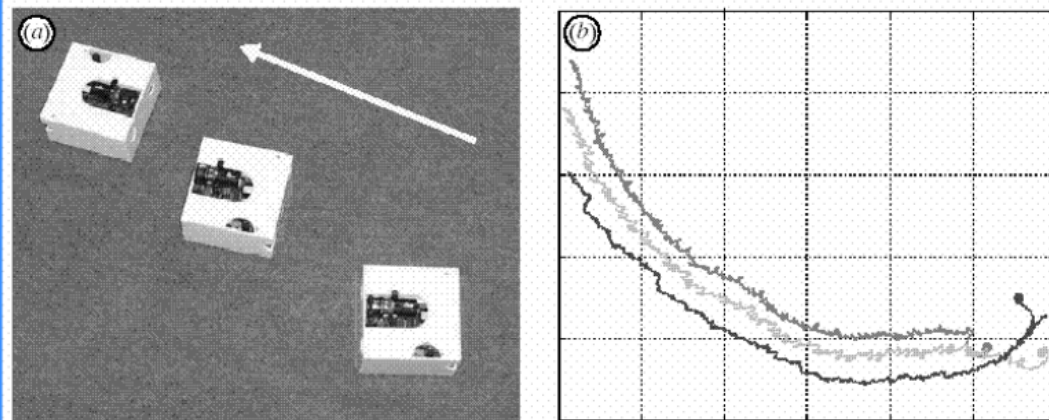


Figure 5. (a) Video still of the team travelling in formation. (b) An example of team trajectory, tracing the position of each robot over a 5 min period. Grid divisions are at 50 cm intervals, robots' initial positions (bottom right) indicated by dots. Data generated in simulation.

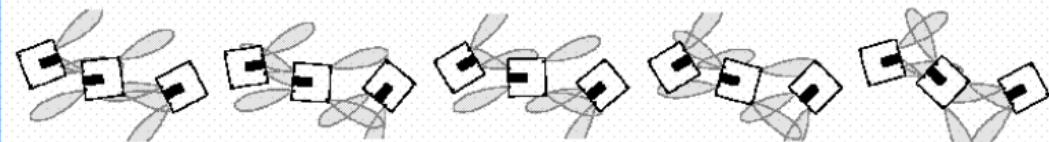


Figure 6. Time sequence illustrating relative positions during formation movement over a short (4 s) period. Robots maintain contact through direct sensing of each other's IR beams.



Quinn

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"In principle" studies

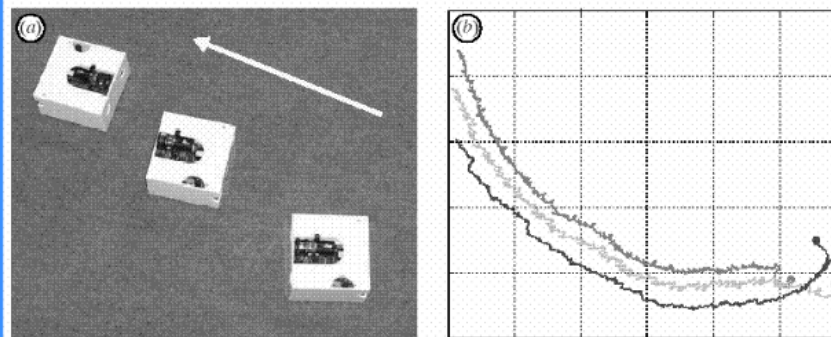
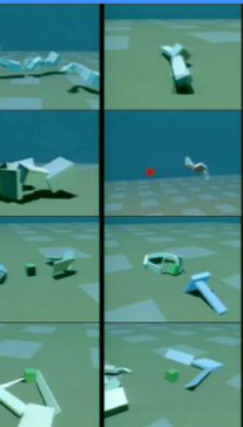
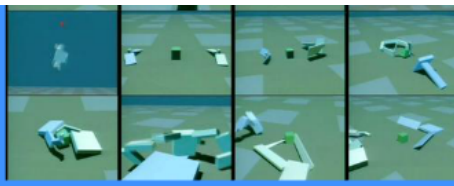


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mainstream
que

optimisation

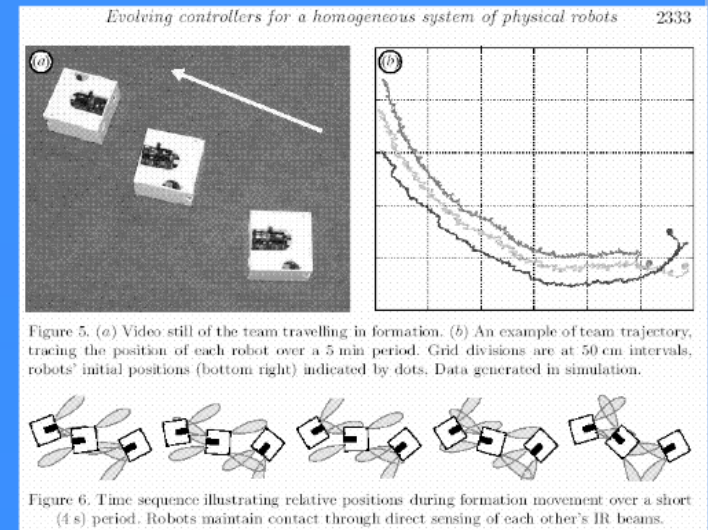


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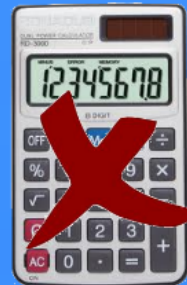
Innovation



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Evolving takes tiiiiiiiiiiiiime

Speed Limit

Almost zero additive knowledge

Primitive
"Origin of Life"
end of the
spectrum

Everything started from scratch

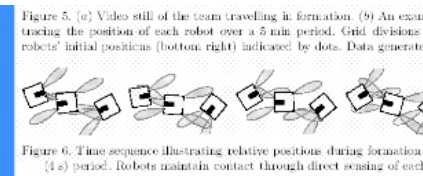
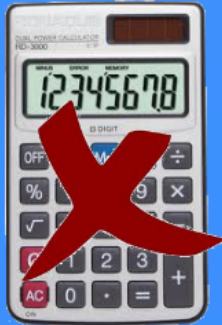


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res

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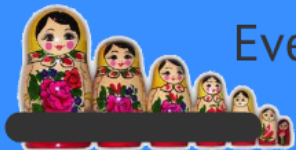
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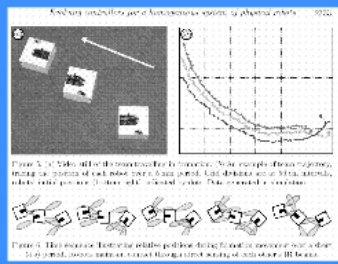
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Speed Limit for Evolution

"20 Questions" are the ab
select one
(and man

In typical evolution, 1 gene

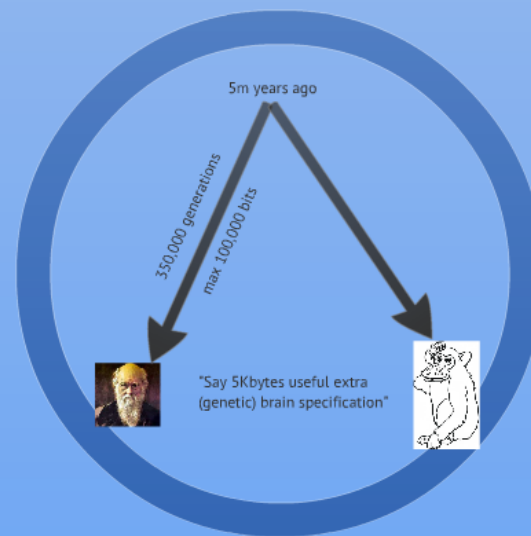
"20-bit
genotype
needs ~2000 generations"
and pro rata for
real-valued
genes

Speed Limit for Evolution (Worden)

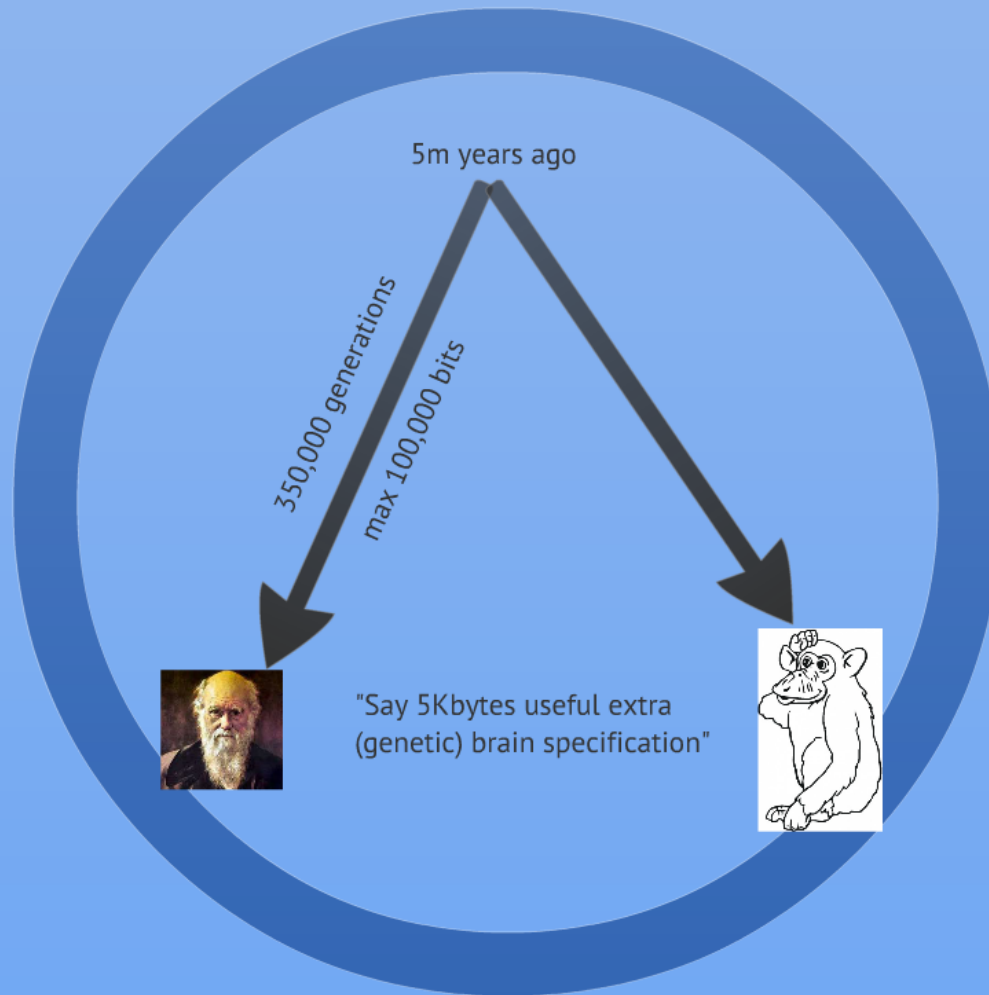
"20 Questions" are the absolute minimum needed to select one out of 1024 possible items (and many more if non-optimal Qns)

In typical evolution, 1 generation $\sim$ 1 non-optimal Qn

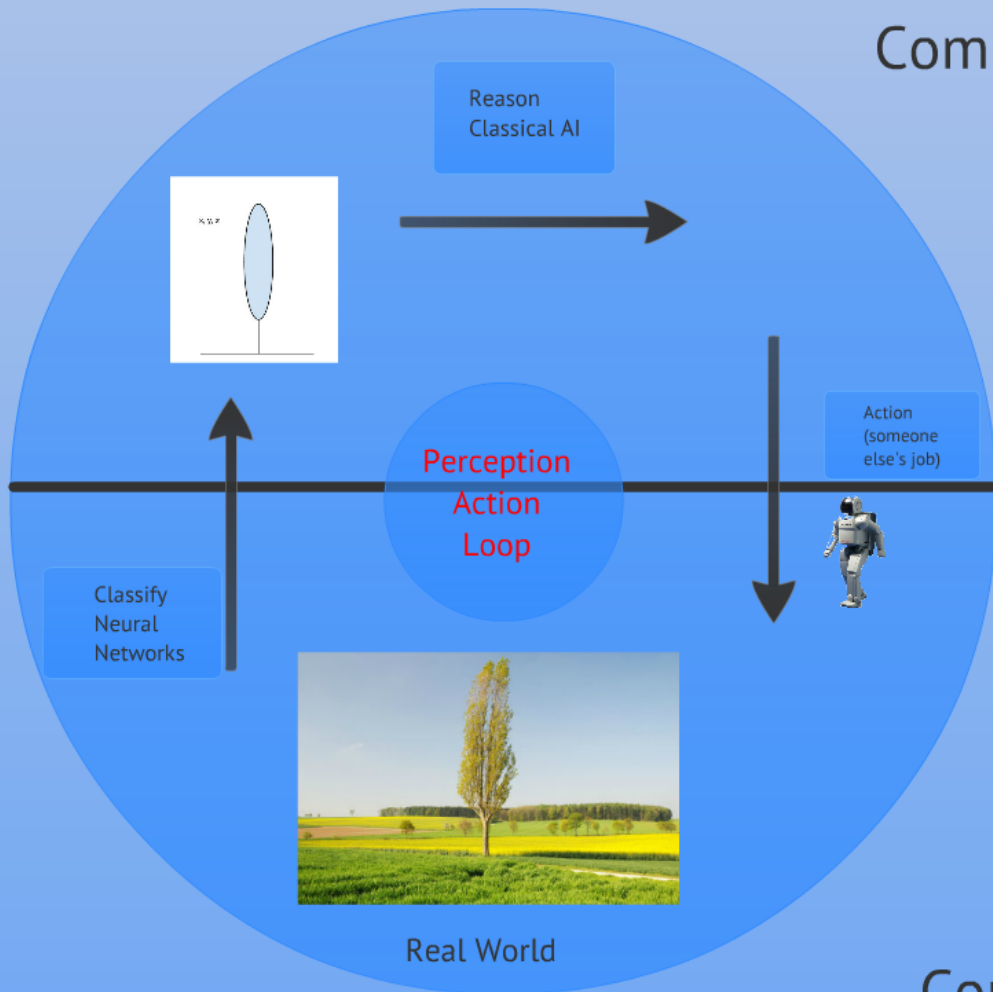
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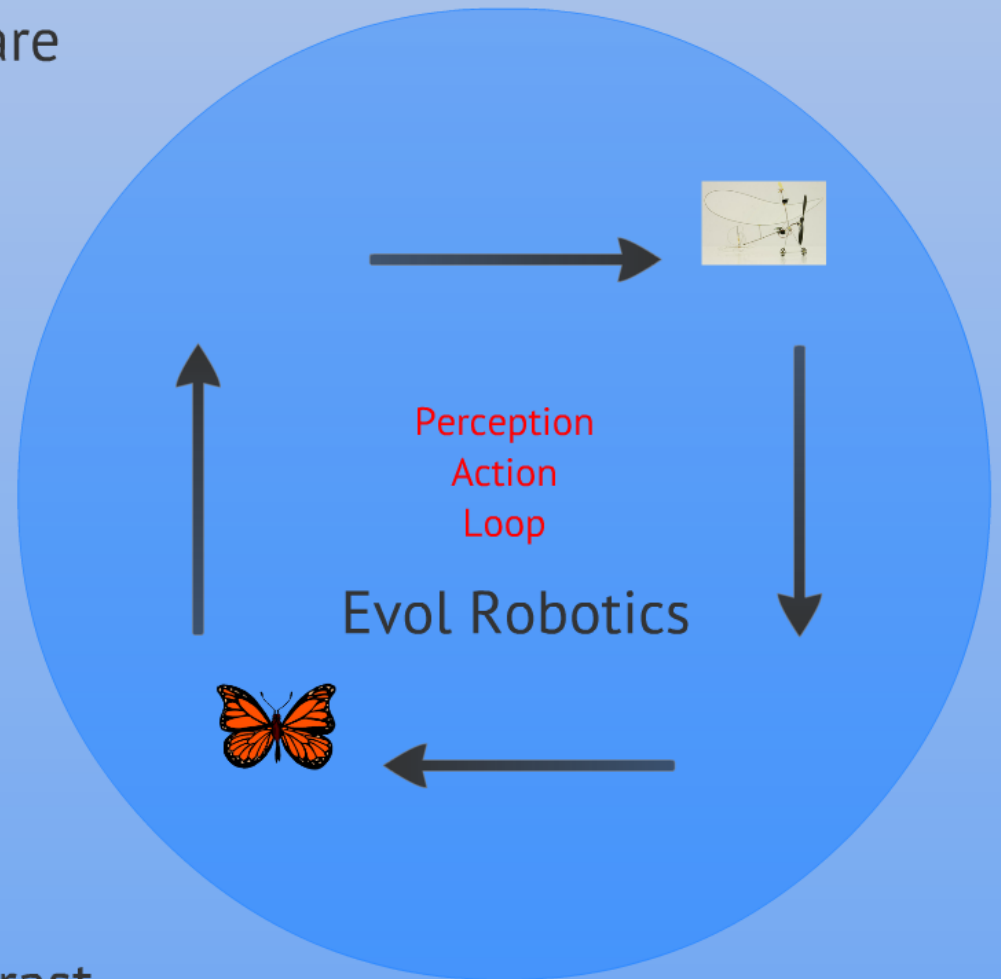
1 generation — 1 non optimal



Compare



Contrast



$$x^2 + y^2 = z^2$$



Rational Thought

"What differentiates
Humans from other animals"

Disembodied Logic
Rigidly constrained worlds
Little/no noise
Chess

Adaptive Behaviour
Robust to changing context



4,000 kms each way
3 or 4 generations/cycle
Weighs a few milligrams
magnetic sense, sun compass
circadian clock, photoreceptors,
smell



"AI always prom

Once delivered

Any suff
indistin

Perspectives on AI

Inman Harvey

Classical AI

Origins



Methods



Successes



Failures

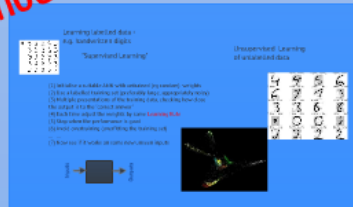


Neural Networks

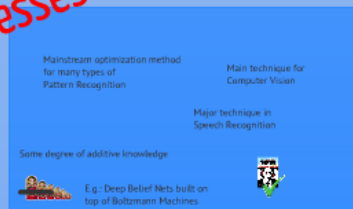
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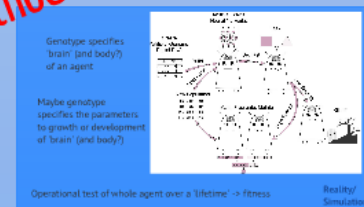


Evolutionary Robotics

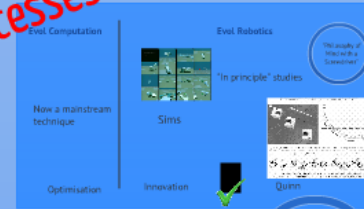
Origins



Methods



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