Research Center for Technology and Art

Seminar Presentation

Introduction to Artificial Life for People who Like AI

Lana Sinapayen

- ALife Introduction
- A short history of Alife
- ALife and AI
- Conclusion & Vision of ALife
- Connection/Demo

https://thegradient.pub/an-introduction-to-artificial-life-for-people-who-like-ai/

ALife Introduction

- ALife is the bottom-up scientific study of the fundamental principles of life.
  Artificial Intelligence researchers ponder the nature of intelligence by trying to build intelligent systems from scratch,
  ALife researchers investigate the nature of "life" by trying to build living systems from scratch.

- Field: biology, chemistry, computer science, astrobiology, physics, complex systems, network sciences, geology, evolutionary science, origins of life research, AI, and animal behavior studies

- What is Life?
  Something that **grows and reproduces** is alive? That definition is far from the messy scientific reality of "life." Many video game simulations include animals that grow and reproduce, and although you could certainly find people arguing that those are alive, the consensus is that "grow and reproduce" is not enough to define "being alive." Likewise, salt crystals grow and cause more crystals to grow around them, but they are not alive.

ALife Introduction

- What is Life?

  what about DNA? DNA is the one common point between all life on Earth. Even if you are looking for life on another planet, DNA is the smoking gun that you should look for.

  One crucial thing about DNA is that it encodes information about cells that can be passed from parent to offspring. If you focus on this function, it does not matter what DNA is made of or what shape it takes -- you can **encode and transfer information** using just anything you like, including 8-letter DNA or a string of 0 and 1 in a computer. Some substrates are better than others under certain conditions, but the function “information transfer” is not dependent on DNA itself. In that sense, ALife is Substrate-Agnostic.

✓ Agnostic (Wiki): 不可知論，或稱不可知主義，是一種哲學觀點，認為形上學的一些問題，例如是否有來世、鬼神、天主是否存在等，是不為人知或者根本無法知道的想法或理論。不可知論者不像無神論者一樣否認神的存在，只是認為人無法知道或無法確認其是否存在，因此不可知論包含著宗教的懷疑主義；不可知論者認為人類不可能得到真理.

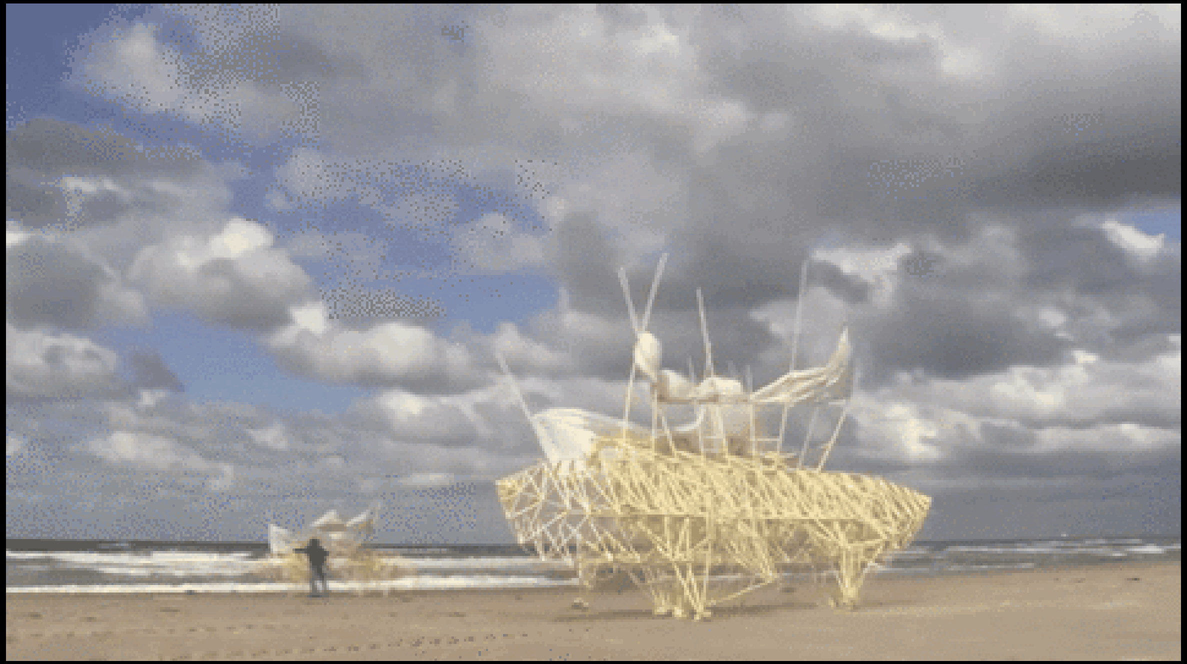
ALife Introduction

- What is Life?

AI researchers develop **programs** that in various ways mimic aspects of known **human intelligence** without necessarily agreeing on what "intelligence" is.

Alife researchers seek to create **dynamical systems** that mimic aspects of known **biological life** without necessarily agreeing on what "life" is.

In other words, ALifers are after a set of functions that can define life as a process and allows you to "**run**" it on a suitable platform under certain conditions, just like you can run a piece of software on many different hardware platforms.



ALife Introduction

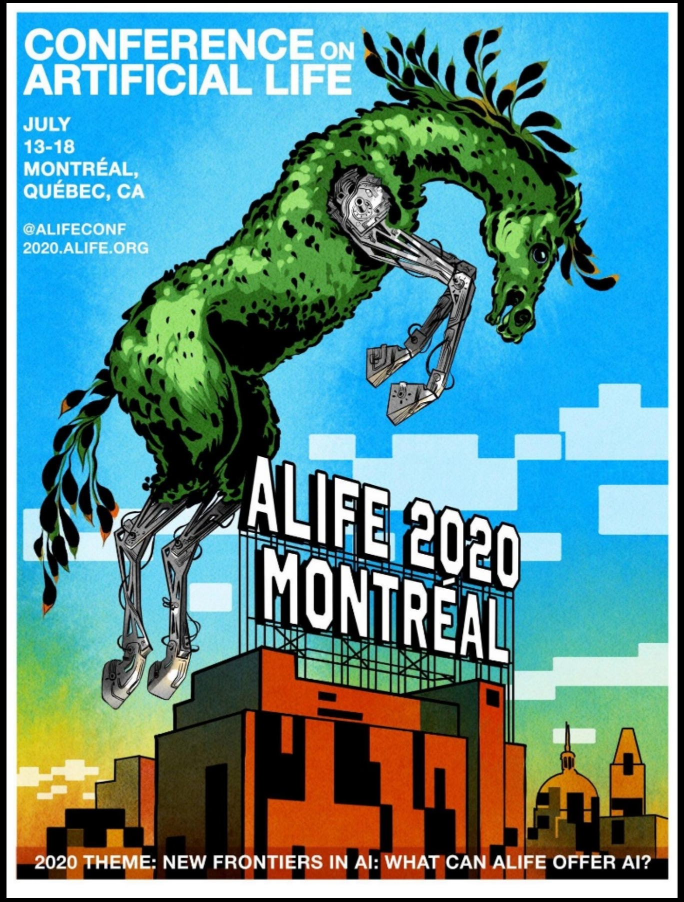
- Definition of ALife
  - ✓ A living organism should perform autopoiesis (i.e. the organism should constantly be “rebuilding” itself by exchanging materials with the surrounding environment), respond to stimuli, adapt to its environment, reproduce and transfer imperfect information to its offspring.
  - ✓ Yet another definition says that life is just any autopoietic chemical system that can be subject to natural selection.

    (Natural selection, survival of the fittest ; 物競天擇, 適者生存)
  - ✓ The current definitions is that if they were productive enough, we would already have built a form of Artificial Life and have a consensus to call it “alive.”

A short history of Alife

- As a scientific field, ALife was officially born when the American computer scientist Christopher Langton organised the first ALife workshop in 1987. Langton coined the name “Artificial Life” and defined it as “the study of artificial systems that exhibit behavior characteristic of natural living systems.”

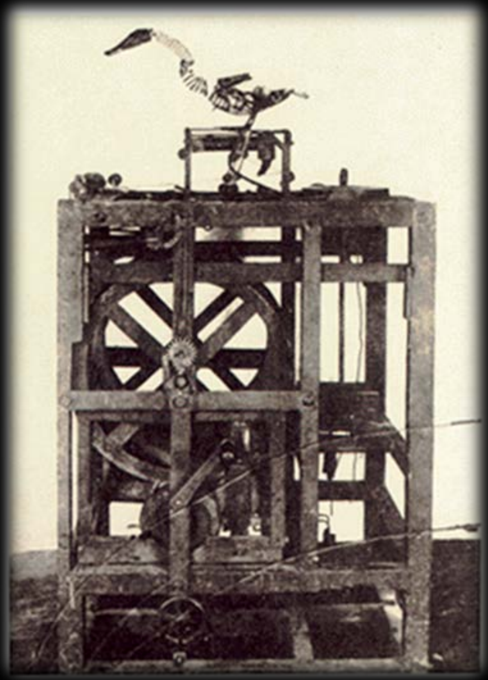
- The field is commonly divided into 3 sub-fields:
  - ✓ Hard ALife, concerned with hardware, covering robotics and new computing architectures
  - ✓ Soft ALife, concerned with software, covering computer simulations (including AI)
  - ✓ Wet ALife, concerned with wetware, and covering chemistry and biology.



A short history of Alife

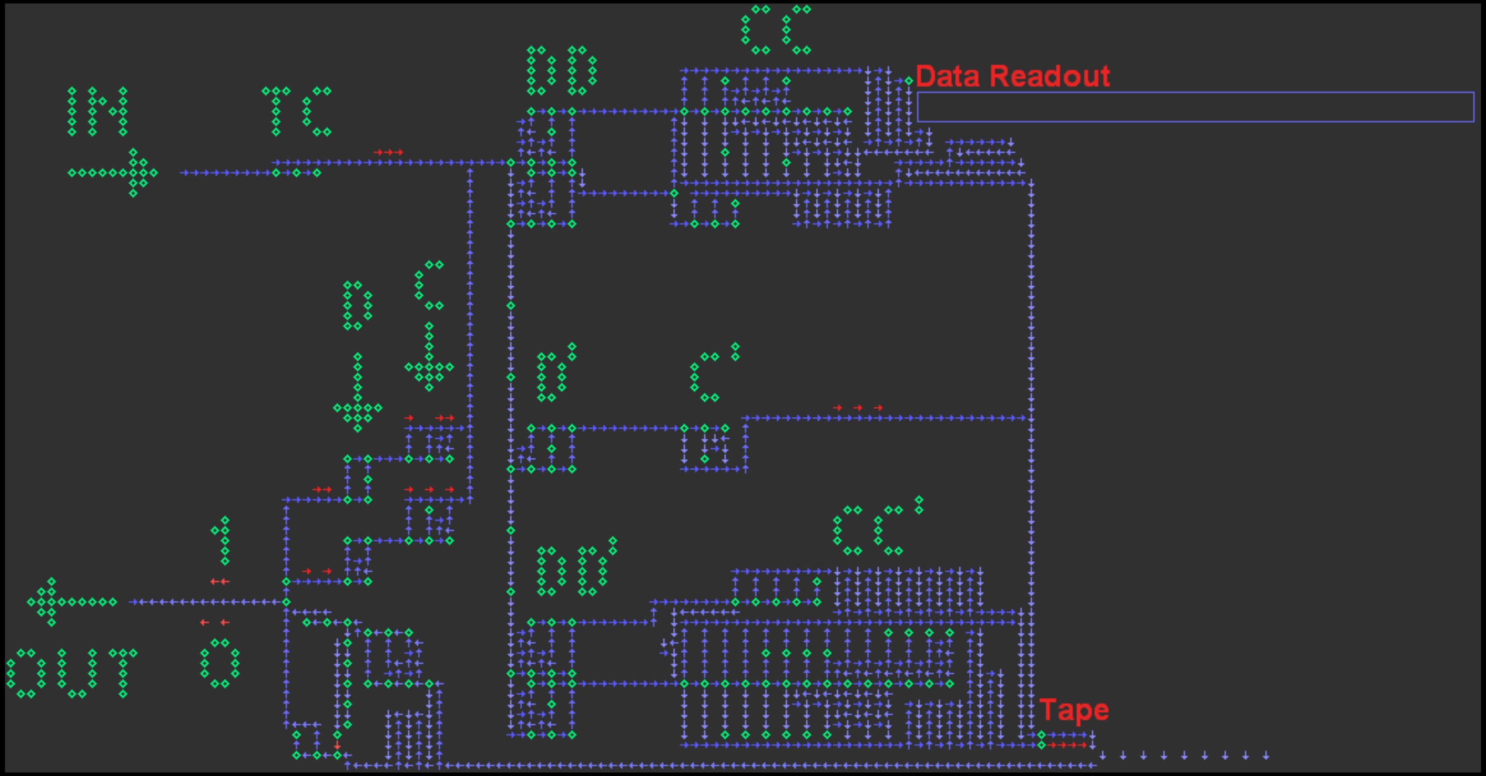
- Yet the philosophy of ALife is much older than the 1980s: the idea that life is a process that can be recreated in an artificial substrate, like a software that can run on different platforms, is at least as old as the Jewish tale of the Golem, a creature made of mud that comes to life when placed in contact with the right words. There are a few documented examples of people trying to reproduce functions of living organisms in artificial media, such as French engineer Jacques de Vaucanson's digesting duck (1739), a mechanical "duck" that could ingest food and excrete pre-loaded feces.

Left: De Vaucanson's "digesting" duck
Right: Jacquard Loom programmed with punched card



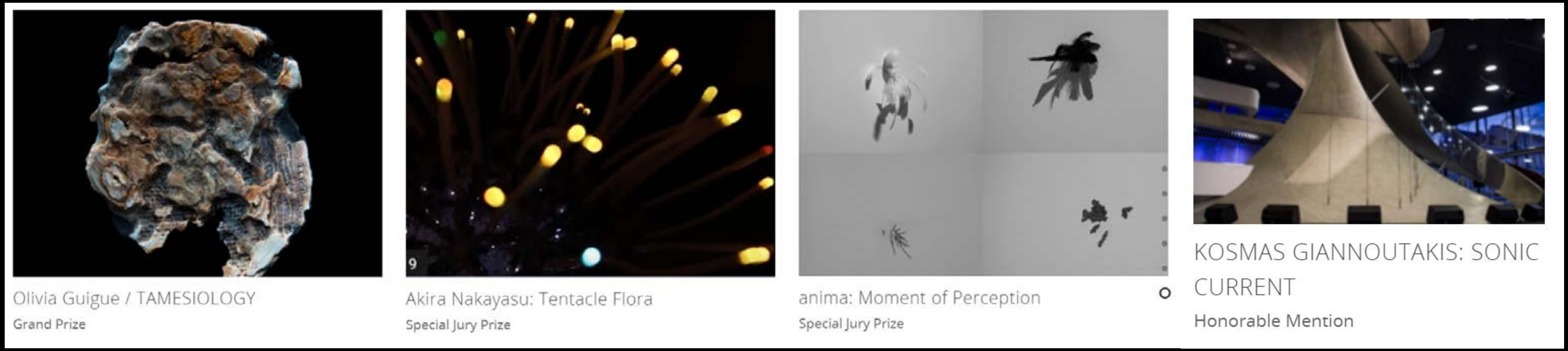
A short history of Alife

- John von Neumann, most famous for his contributions to mathematics, game theory, and computing, also rigorously researched the conditions for self-replication in cellular automatons that he simulated with paper and pencil. He found rules that allowed a 2-dimensional automaton to build a copy of itself based on internally stored information, and that was before the discovery of DNA! Von Neumann then became interested in the evolution of complexity.



A short history of Alife

- ALife has also always had strong ties with the arts, to the point that Art could be considered as a 4th subfield: ALife simulations are often exhibited in media galleries, ALife-based androids have conducted operas, and the 2018 ALife conference had an art contest.

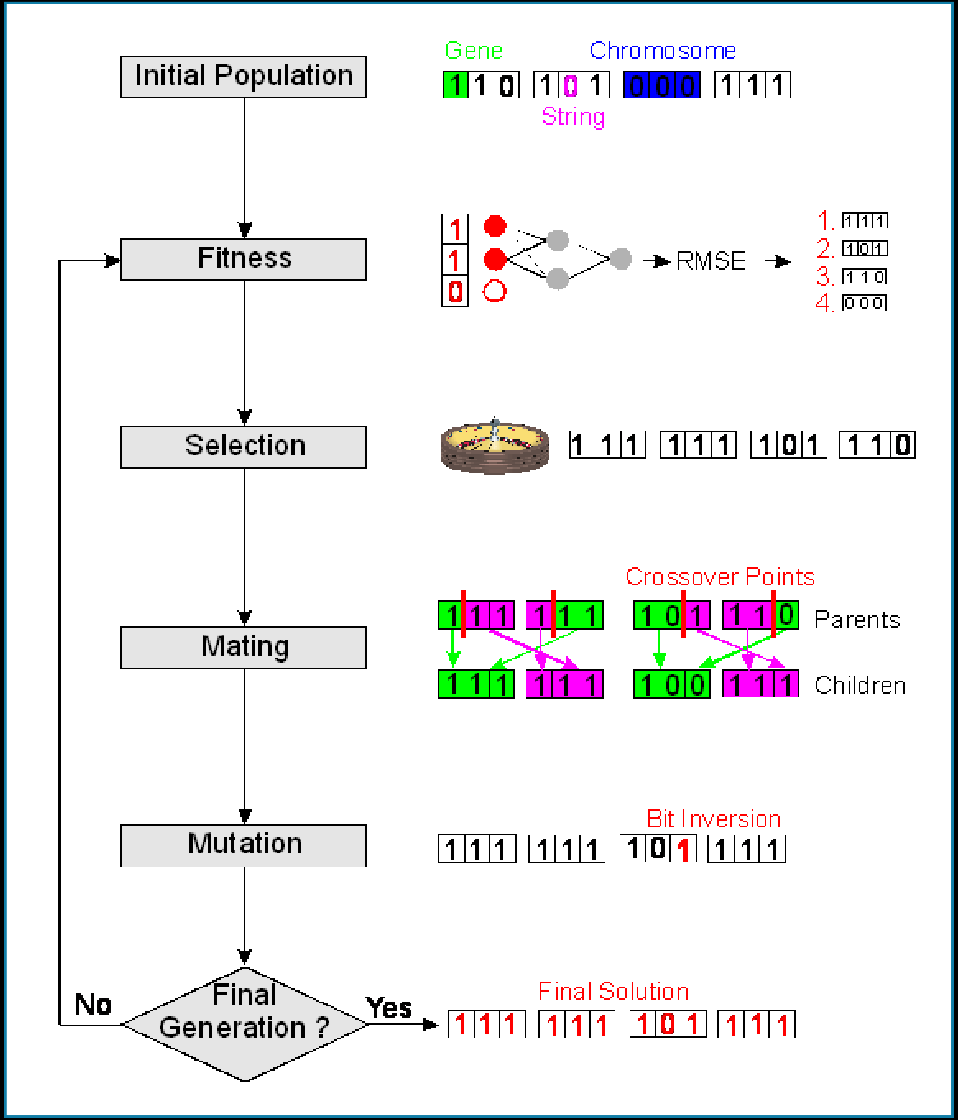


ALife and AI

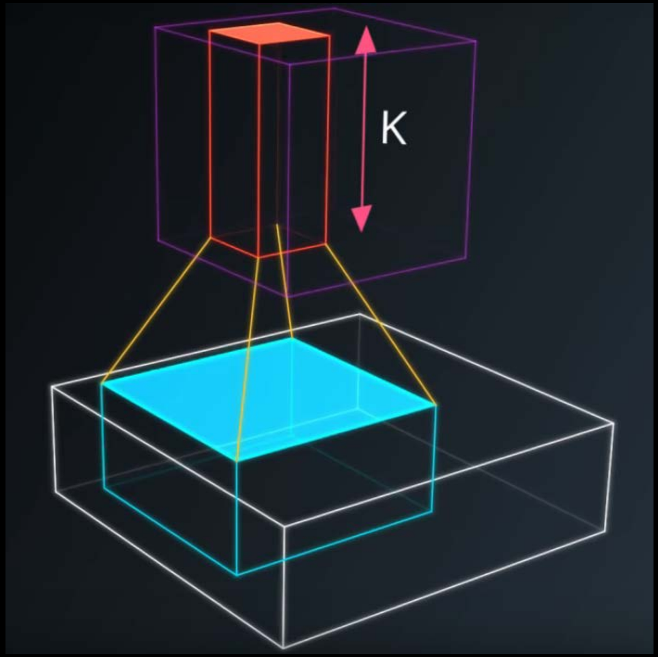
- The concept of Genetic Algorithms itself also originates within the ALife community, with John Holland's pioneering book "Adaptation of Natural and Artificial Systems" in 1975, presenting his work on complex adaptive systems and Genetic Algorithms.
- ALife is currently experiencing a resurgence of interest from the AI community, but the mutual influence goes way back, with Deep Learning pioneers such as Geoffrey Hinton (Google Brain) having been influenced by the ideas of prominent ALife researchers such as Inman Harvey.
- Kenneth O. Stanley, head of Uber AI Labs, is also a respected member of the ALife community for his insightful research on Open Endedness. Stanley's book "Why Greatness Cannot be Planned" touches to the most canonical of ALife's research topics: Open Ended Evolution (OEE). Stanley supervised the creation of Pic Breeder, an online collaborative OEE art project where pictures "reproduce" and evolve.
- Stanley also created a new class of Genetic Algorithms used notably for neural network optimization. Stanley's NEAT algorithm's most striking feature is its focus on optimizing for diversity of solutions and not solely performance, resulting in solutions that beat the classical performance-only optimization approaches. NEAT was awarded the 2017 International Society for Artificial Life Award for Outstanding Paper of the Decade.

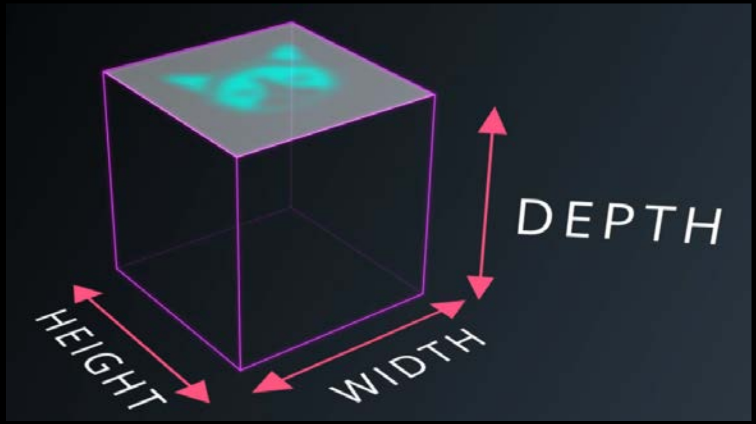
ALife and AI

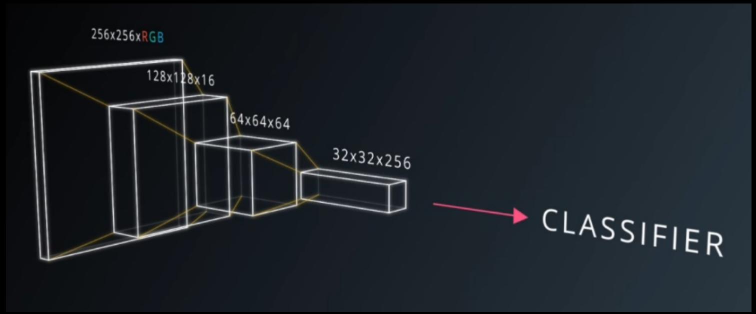
Genetic Algorithms

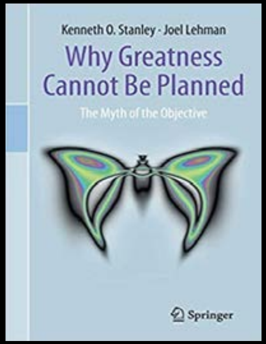


Deep Learning: go deeper, get more feature

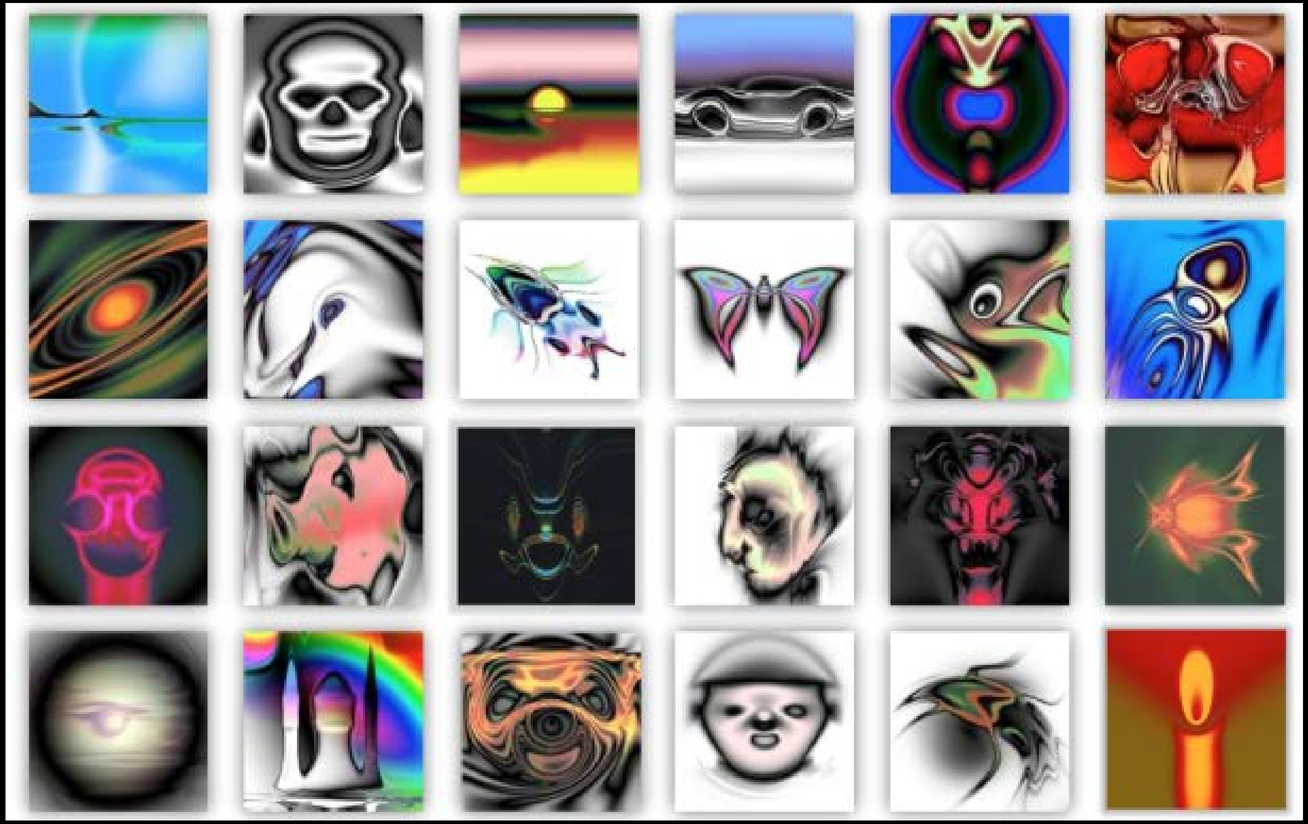








Why Greatness Cannot be Planned



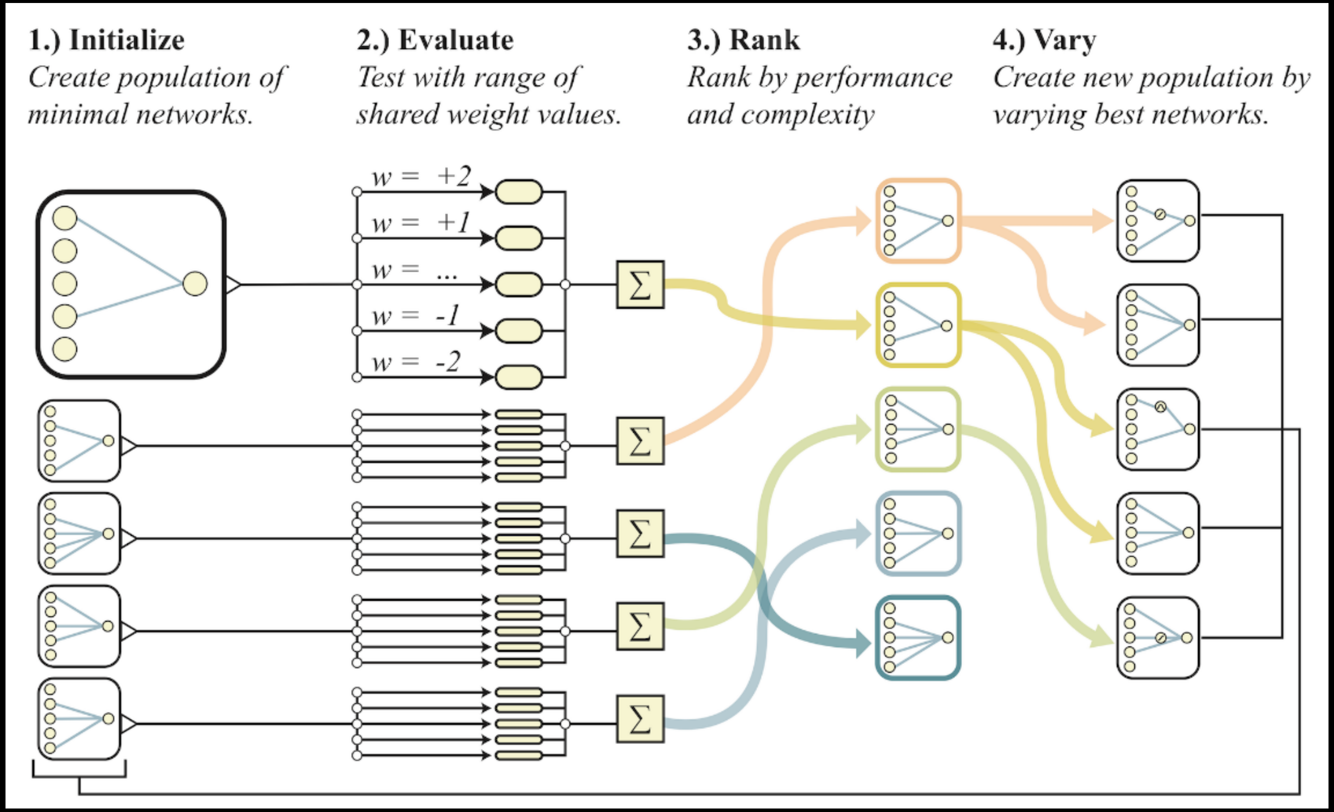
在《Why Greatness Cannot Be Planned》中，作者 Kenneth O. Stanley發現，當用家嘗試用作者設計的軟件 — 故意孕育特定的圖像的時候，沒有一個人成功。如果一個用家嘗試創造一張圖片：例如一張汽車的圖片。用家是沒有可能在合理數量的世代交替中孕育出這張圖片。而事實上這張汽車的圖片是由一個外星人的面演變出來的。書中其中一個要點就是說明了，一個最終成品和一開始的踏腳石沒有任何相似的地方。

在這本書裏，作者說明了人工智能的發展已經展現了這個原則：一個可以步行的人工智能，起先沒有什麼和步行相似。然後作者推展這個原則到創意的過程和日常生活。究竟我們在賴以為常的情況下設置一些難以一下子達成的目標，是否一個不可能的任務？ 如果這些活動是一些像優化問題的難題，那我們的目標就是一個優化的度量衡。但作者的發現說明了，優化一個可測量的目標不會是一個完整的解決方法。因為有時候你需要違反您所定立的目標來完成優化。

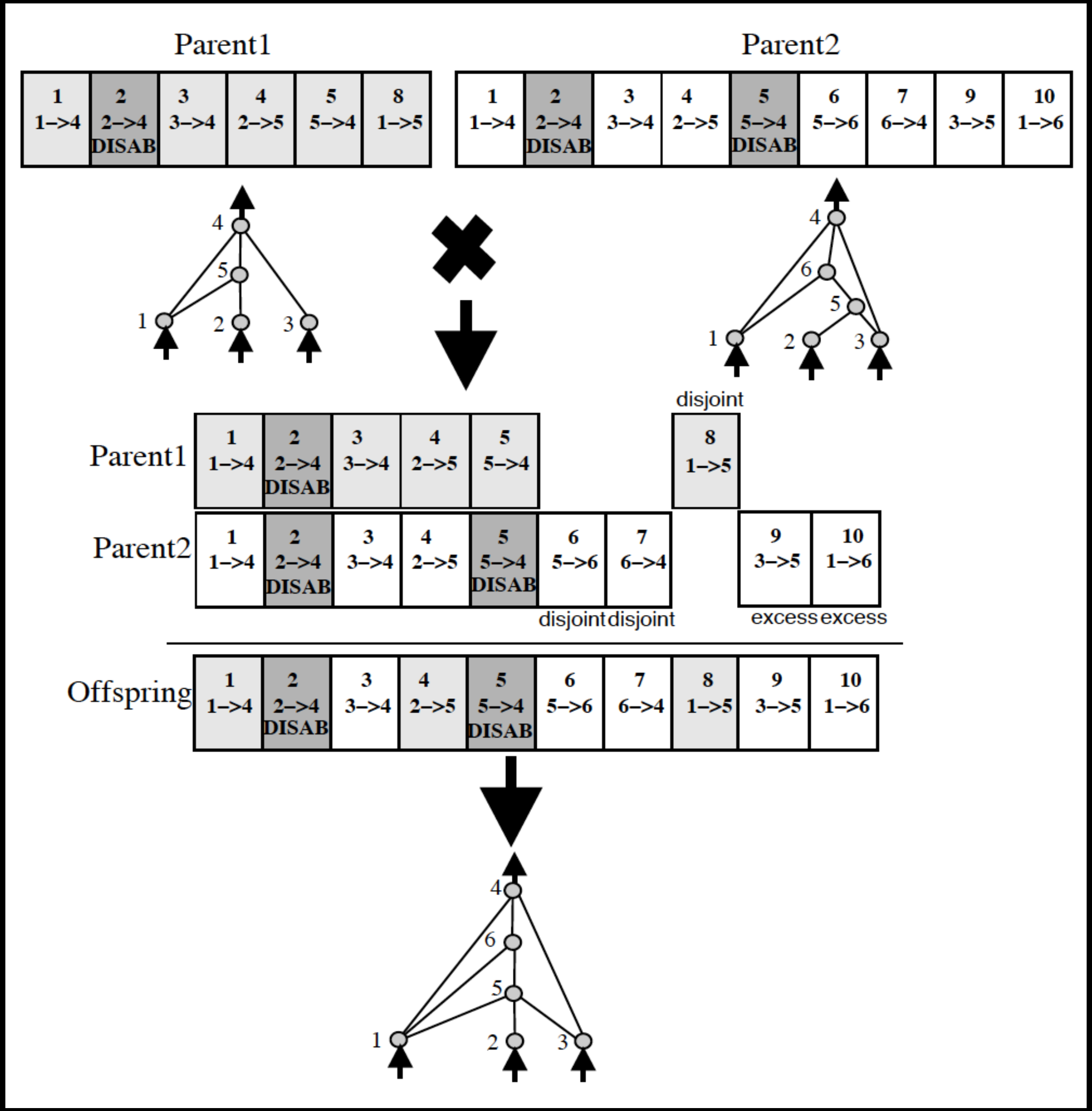
NEAT algorithm

NeuroEvolution of Augmenting Topologies

NEAT process:

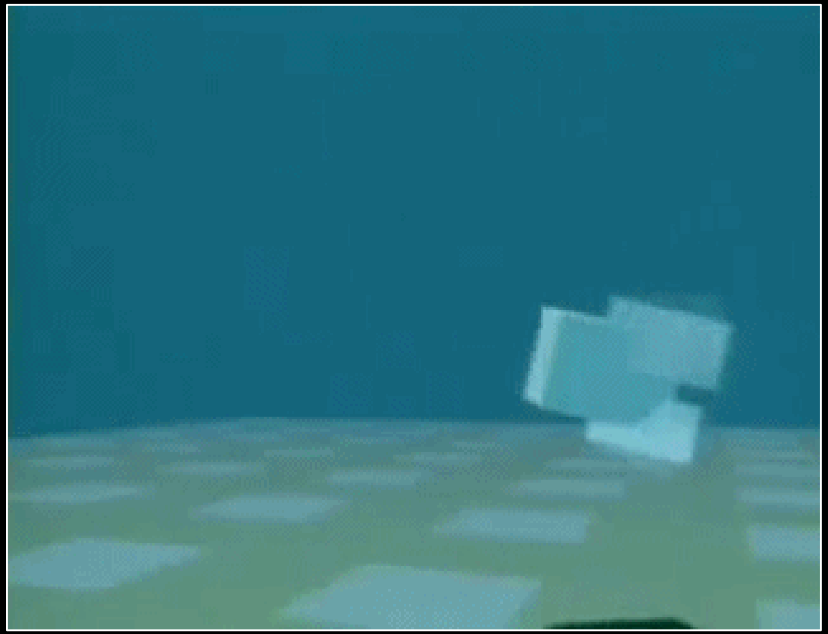


NEAT with Genetic Algorithms :

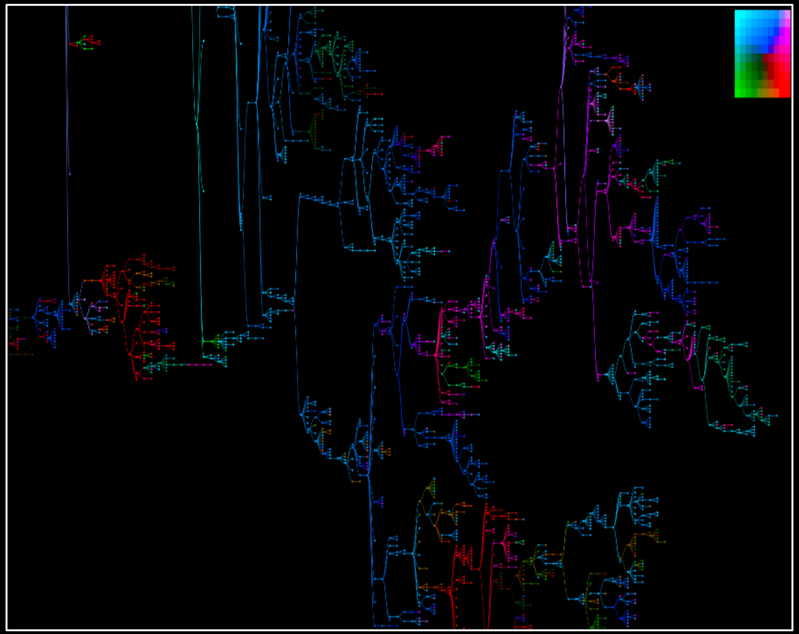


ALife and AI

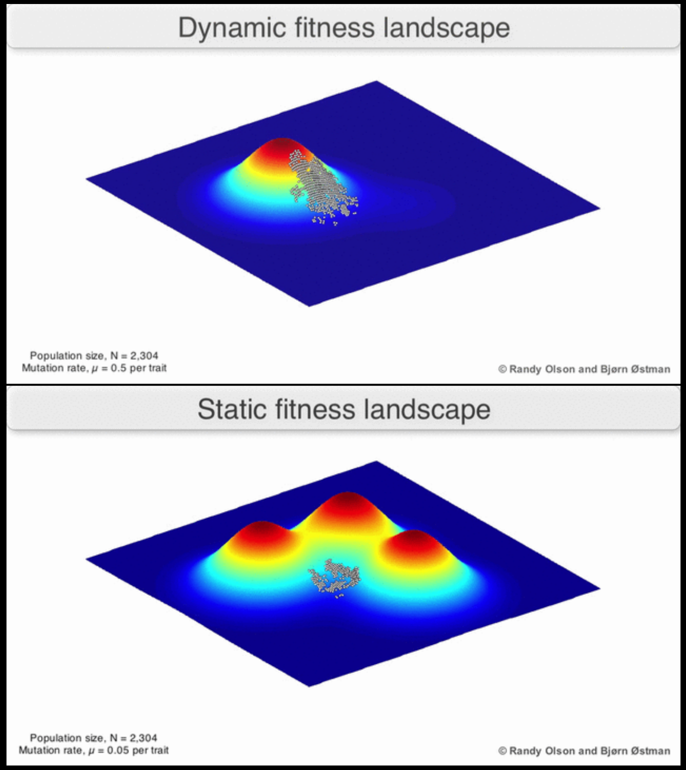
- The AI and Machine Learning communities may have forgotten the ALife origins of Genetic Algorithms, but they never stopped being a big area of research in our field. The most famous example is probably Karl Sims' evolved virtual creatures, but more recent work on GA includes Emily Dolson's work on the effect of spatial distribution on the speed of evolution or Artem Kaznatcheev's work on computational complexity in fitness landscapes.



Virtual Creatures, Karl Sims



Spatial distribution on the speed of evolution, Emily Dolson



Fitness landscapes, Artem Kaznatcheev

Conclusion and Vision of ALife

In the future of my field, the authors see 3 big avenues:

- **AI look towards ALIfe**: the authors think we are seeing the first signs of the next AI winter, a period where people lose confidence in AI research and funding dries out. Some AI practitioners see limits in the Deep Learning boom and in the last few years, have started to look towards ALife for new ideas.
- **AI/ALife merging:** The thing with ALife is that if you manage to build Artificial Life, and apply evolution to it, if you do it right, you must end up with intelligent systems. In my opinion, there cannot be AI without ALife first, and therefore my vision of the future is the merging of both fields. This big merger would be part of an even bigger advance for ALife: the synthesis of Open Ended Evolution (OEE) in an artificial system. OEE is this idea that some systems get exponentially more complex with time, and that complexity never ceases to increase.
- **New life discovery**: the last, and probably biggest, event that could happen for ALife would be the discovery of life on another planet. Unfortunately, for now, we only know one type of life. It is hard to do science when your sample size is N=1. Finding any other kind of life would give us tremendous knowledge about what is important and what doesn't matter to build life.It would completely change the way we approach the question of “what is life” and it would lead to unprecedented advances in ALife, both in theory and in practice.

Conclusion and Vision of ALife

To close this primer, let me share a few papers presented at the 2019 Conference on ALife (find all published papers in open access here). This purely subjective selection includes one paper on Hard ALife, one on Wet ALife, one on Soft ALife, and one Art ALife paper. For more resources to deepen your ALife knowledge, scroll to the end of this article.

- Hard ALife: “The ARE Robot Fabricator: How to (Re)produce Robots that Can Evolve in the Real World”, by Matthew F. Hale, Edgar Buchanan, Alan F. Winfield and Jon Timmis.
- Soft ALife: “On Sexual Selection in the Presence of Multiple Costly Displays” by Clifford Bohm, Acacia L. Ackles, Charles Ofria and Arend Hintze.
- Wet ALife: “Synthetic Biology in the Brain: A Vision of Organic Robots”, Ithai Rabinowitch.

Research Center for Technology and Art

Seminar Presentation

Introduction to Artificial Life for People who Like AI

Lana Sinapayen

- ALife Introduction
- A short history of Alife
- ALife and AI
- Conclusion & Vision of ALife
- Connection/Demo

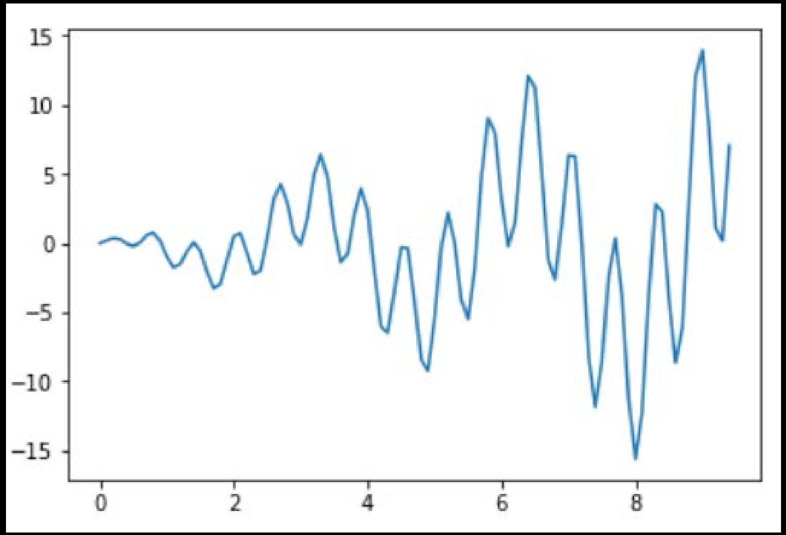
https://thegradient.pub/an-introduction-to-artificial-life-for-people-who-like-ai/

Demo: Genetic Algorithms

Target: to find the maximum of this function

Max: Sin(10X)X + Cos(2X)X

```
def F(x): return np.sin(10*x)*x + np.cos(2*x)*x
```



initialize the pop DNA
(POP_SIZE = 100 , DNA_SIZE = 10)

```
pop = np.random.randint(2, size=(POP_SIZE, DNA_SIZE))
pop.shape
```

```
(100, 10)
```

Random initial solution:

	0	1	2	3	4	5	6	7	8	9
0	0	0	0	0	1	0	0	0	1	0
1	1	1	0	1	1	0	0	0	0	0
2	1	0	0	0	0	0	1	0	0	1
3	0	0	0	0	0	0	0	0	1	0
4	0	0	0	0	0	0	0	1	0	0

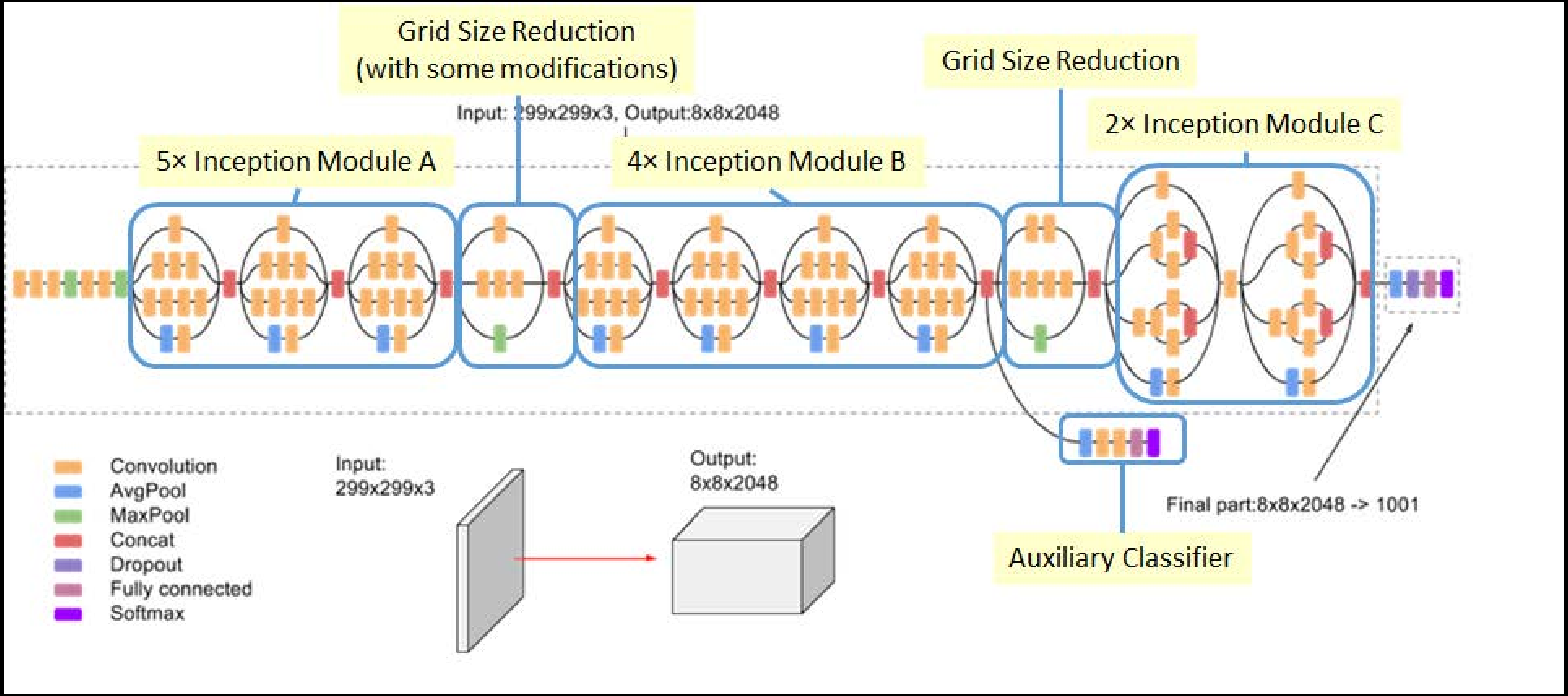
Algorithms design:

```
# find non-zero fitness for selection
def get_fitness(pred): return pred + 1e-3 - np.min(pred)


# convert binary DNA to decimal and normalize it to a range(0, 5)
def translateDNA(pop): return pop.dot(2 ** np.arange(DNA_SIZE)[::-1]) / float(2**DNA_SIZE-1) * X_BOUND[1]


def select(pop, fitness):    # nature selection wrt pop's fitness
    idx = np.random.choice(np.arange(POP_SIZE), size=POP_SIZE, replace=True,
                           p=fitness/fitness.sum())
    return pop[idx]


def crossover(parent, pop):     # mating process (genes crossover)
    if np.random.rand() < CROSS_RATE:
        i_ = np.random.randint(0, POP_SIZE, size=1)                         # select another individual from pop
        cross_points = np.random.randint(0, 2, size=DNA_SIZE).astype(np.bool)   # choose crossover points
        parent[cross_points] = pop[i_, cross_points]                         # mating and produce one child
    return parent


def mutate(child):
    for point in range(DNA_SIZE):
        if np.random.rand() < MUTATION_RATE:
            child[point] = 1 if child[point] == 0 else 0
    return child
```

Then Go!!!

Demo: Deep Learning

Model: **Inception** V3, with 42 layers deep, the computation cost is only about 2.5 higher than that of GoogLeNet, and much more efficient than that of VGGNet



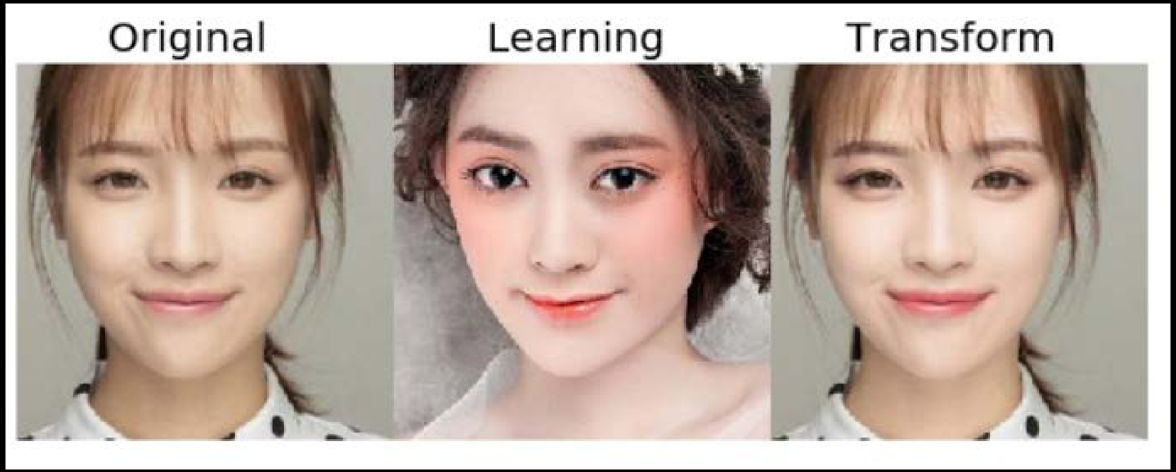
Demo: Deep Learning

Painting Styles Learning:

Un dimanche après-midi à l'Île de la Grande Jatte, 1884,
Georges Seurat,
傑特島的星期日下午,
法國畫家喬治·修拉

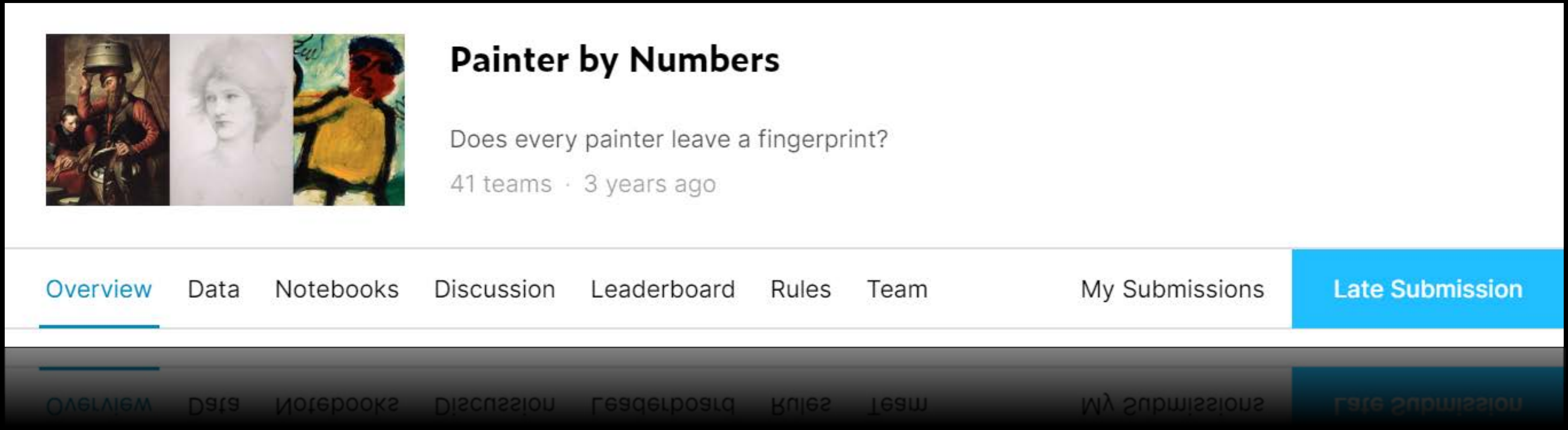
Demo: Deep Learning

Makeup Learning：美肌美顏/一鍵上妝

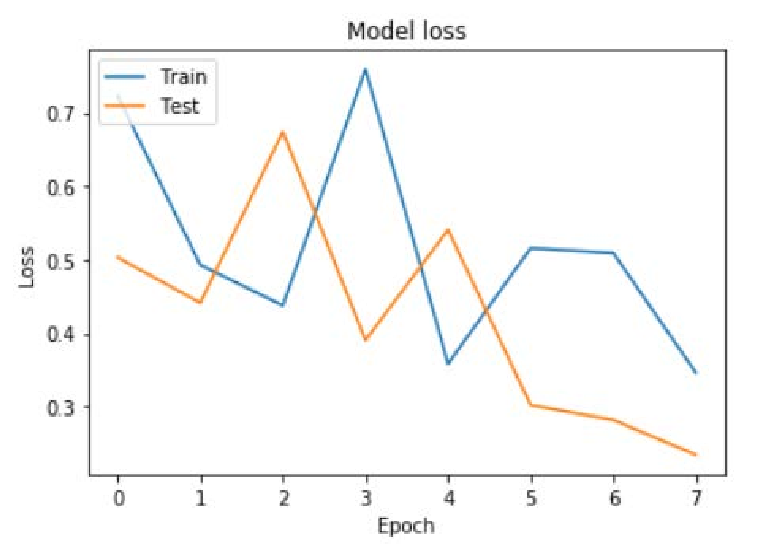


Painting Styles/Makeup Learning are all Texture Learning (without Geometry)

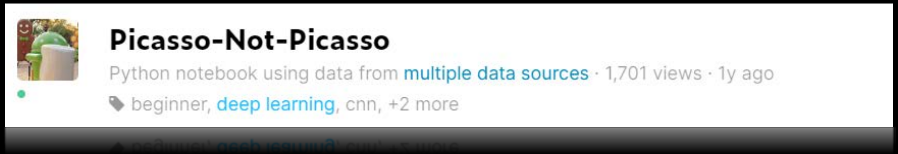
Connection


Painter by Numbers
Does every painter leave a fingerprint?
41 teams · 3 years ago
Overview
Data
Notebooks
Discussion
Leaderboard
Rules
Team
My Submissions
Late Submission


Model accuracy
Train
Test
Accuracy
Epoch
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0
1
2
3
4
5
6
7


Model loss
Train
Test
Loss
Epoch
0.7
0.6
0.5
0.4
0.3
0
1
2
3
4
5
6
7

Connection



Picasso:

Not Picasso:

Connection

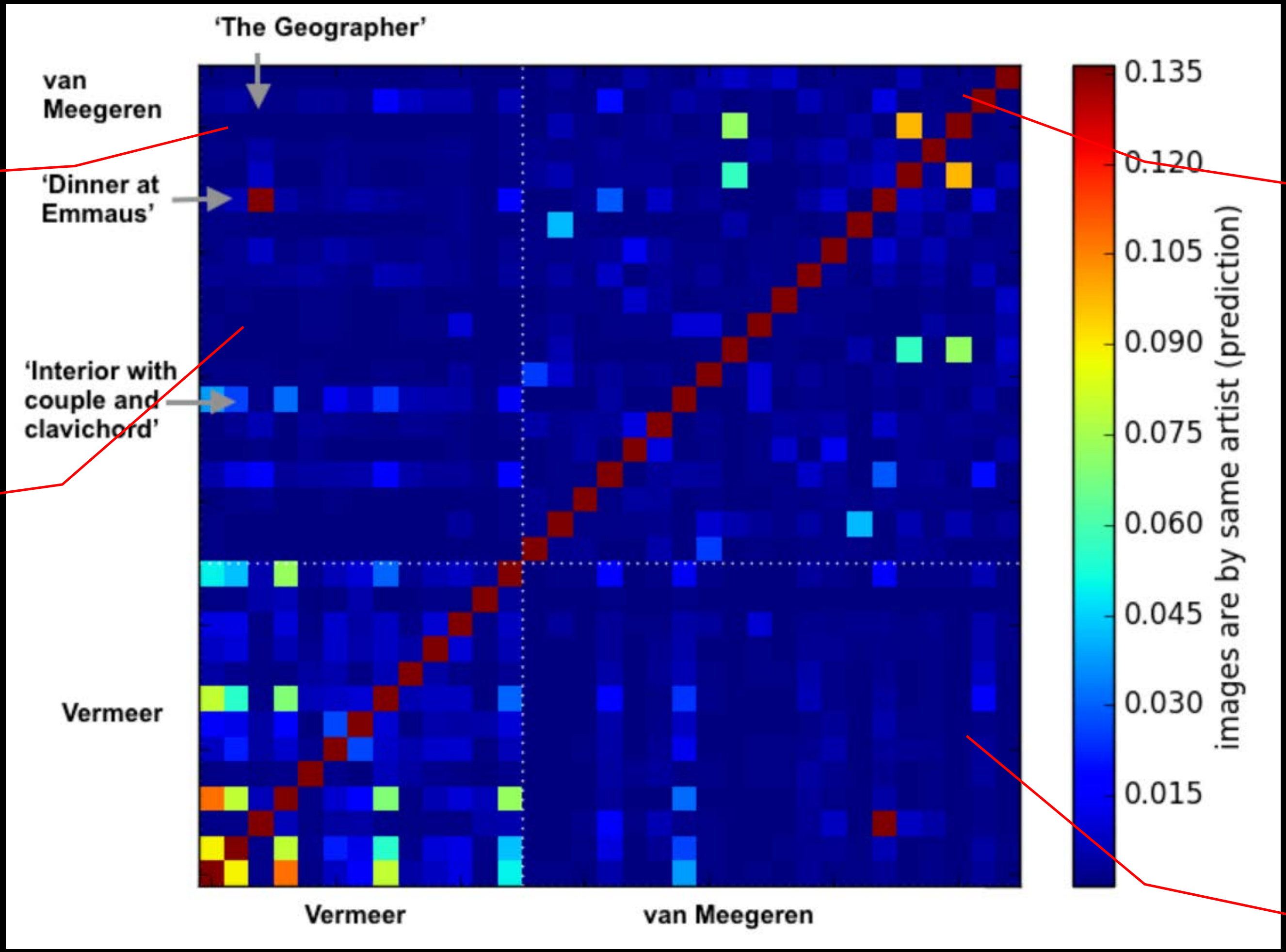
Challenge: Van Meegeren (1889-1947) and Vermeer (1632-1675)

Connection

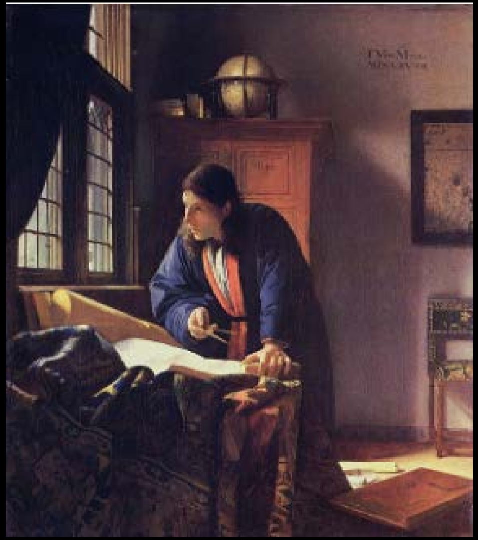
Dinner at Emmaus (van Meegeren)

Interior with couple and clavichord (van Meegeren)

The pairwise comparison table for first-place winner orange-nejc's predictions for van Meegeren and Vermeer paintings in the test set



The Milkmaid (Vermeer)



The Geographer (Vermeer)

Connection

Go deeper, we can see more

Inception