



ARTIFICIAL LIFE, LEARNING THROUGH EMERGENT BEHAVIOR

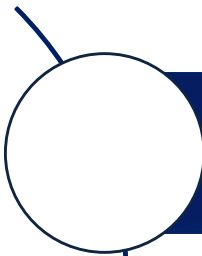
Fundamentals of Artificial Intelligence

Session 04

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Agenda



Artificial Life



Learning through Emergent Behavior

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Artificial Life

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Artificial Life

- ❑ Also known as Alife
- ❑ The bottom-up scientific study of the fundamental principles
- ❑ 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
- ❑ As a scientific field:
 - ❖ ALife was officially born when the American computer scientist Christopher Langton organized 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.”



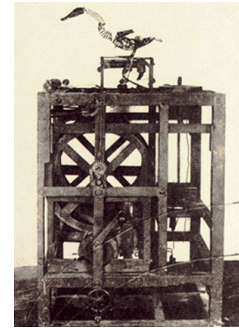
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Long history

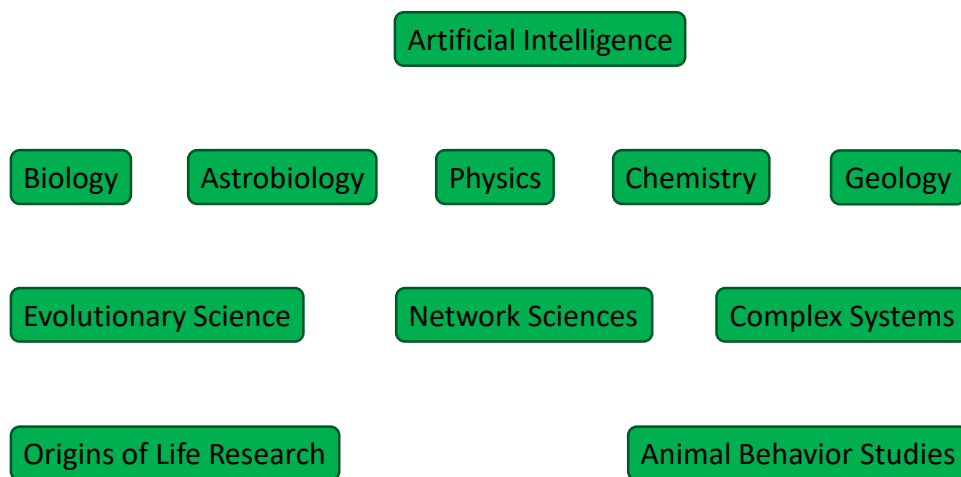
- ❑ Philosophy of ALife is much older:
 - ❖ The idea that life is a process that can be recreated in an artificial substrate, like a software that can run on different platforms,
 - ❖ Old as the Jewish tale of the Golem, a creature made of mud that comes to life when placed in contact with the right words,
 - ❖ French engineer Jacques de Vaucanson's digesting duck (1739), a mechanical "duck" that could ingest food and excrete pre-loaded feces.
- ❑ De Vaucanson's mechanical loom for weaving fabric was more successful than his duck;
 - ❖ The loom was programmable using punched cards
 - ❖ Inspired Charles Babbage, inventor of the first mechanical computer with Ada Lovelace.
- ❑ Since then, ALife and computing never stopped influencing each other.



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Different fields



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What is life?

- ❑ The question “what is life” is still unanswered
 - ❖ Something that grows and reproduces is alive
 - ❖ It is too far from reality
- ❑ Many video game simulations include animals that grow and reproduce
 - ❖ Certainly there are people arguing and believing that those are alive
- ❑ Salt crystals grow and cause more crystals to grow around them, but they are not alive
- ❑ The consensus is that “**grow and reproduce**” is not enough to define “**being alive.**”

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What is life?

- ❑ What about DNA?
 - ❖ In school, we learned that 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, right?
- ❑ One crucial thing about DNA, is that it encodes information about cells that can be passed from parent to offspring (its function)
 - ❖ Beyond the fact that “it is a double helix made of Adenine Thymine Guanine and Cytosine” (its substrate)
- ❑ Therefore it does not matter what DNA is made of or what shape it takes, we can encode and transfer information
 - ❖ Including *8-letter DNA* or a string of 0 and 1 in a computer

Simply speaking: seek to create dynamical systems that mimic aspects of known biological life without necessarily agreeing on what “life” is

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“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.”

What is Alive?

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Features

- ❑ The more general your rules and the more platforms you can use while maintaining the functions, the better.
- ❑ Functions:
 - ❖ The organism should constantly be “rebuilding” itself by exchanging materials with the surrounding environment
 - a living organism should perform “autopoiesis”
 - ❖ Respond to stimuli
 - ❖ Adapt to its environment
 - ❖ Reproduce
 - ❖ Transfer imperfect information to its offspring

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ALife

- ❑ 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
- ❑ Of course ALife Art
 - ❖ ALife simulations are often exhibited in media galleries,
 - ❖ ALife-based androids have [*conducted operas*](#),
 - ❖ 2018 ALife conference had an [*art contest*](#)



Karl Sims' evolved virtual creatures

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Android Opera "Scary Beauty" world premier at The National Museum of Emerging Science and Innovation (Miraikan), July 22, 2018

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ALife beyond AI

- ❑ ALife concerned with interactions between creatures - Swarm Dynamics
 - ❖ From complex swarming patterns in simplistic simulated birds, that inspired the CGI warrior crowds in your favorite movie, to swarming "smart" slime mold made of individual fungi, to swarm chemistry,
 - ❖ The overarching principle behind swarm research is the search for emergence
- ❑ An emergent property is something that is "more than the sum of its parts":
 - ❖ A form of complexity that unexpectedly arises from simpler parts
- ❑ Life itself is thought of as an emergent process;
 - ❖ An isolated pile of molecules is not as "interesting" or complex as a cell made of these same molecules.

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Learning through Emergent Behavior

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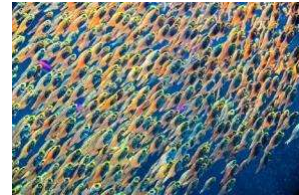
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Learning through Emergent Behavior

❑ Nature has plenty of examples

- ❖ Honey Bees
- ❖ Fish
- ❖ Bird
- ❖ Ants
- ❖ Termites



❑ They have found a way to amplify intelligence

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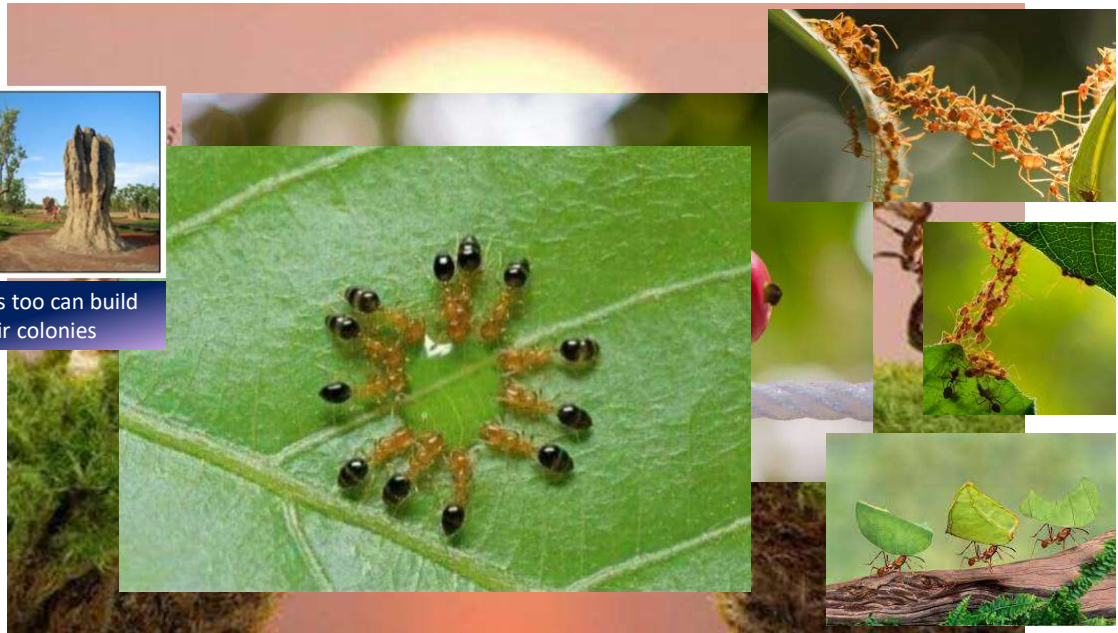
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Ants



Termites too can build their colonies

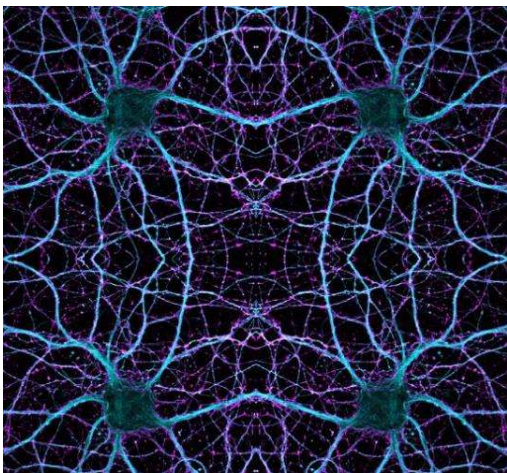


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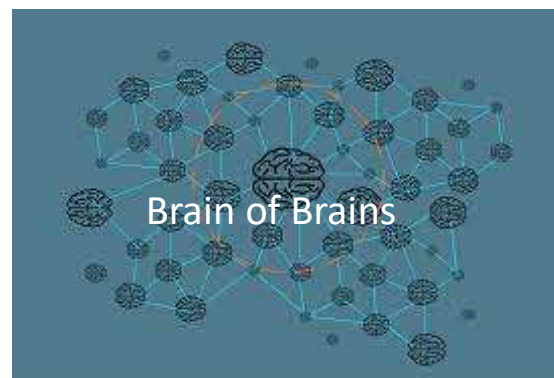
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Super Intelligence

Brain - intelligence



Swarm – super intelligence



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Swarm Intelligence

- ❑ Nature has found ways to Swarm Intelligence also referred as “Hive intelligence”
- ❑ No its not crowd sourcing or surveys or opinion polls
- ❑ Its deeply connected, real time system with feedback loops where multiple brains are participating
 - ❖ Different research papers give different names – “Hive Mind”, “Swarm Mind”

- ❑ Let's take an example – Honey bees

When the bee colony splits, a new queen will stay with the existing hive and the older queen will take a portion of the female worker bees and a few male drones as they search for a new home.



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Example Honey Bees

- ❑ There are almost 10,000 bees in a hive
- ❑ They need to search for new home whenever their group splits
- ❑ Individual bees search the environment without prior information about the possible location of food sources or nest sites
- ❑ Amazing to see how social insects trade-off exploitation with exploration
- ❑ It's a life and death situation for them
 - ❖ 100s of bees
 - ❖ Scout more than 70 sq. km .
 - ❖ Identify dozens of candidate locations
 - ❖ Then zero on to best possible location

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Multidimensional Problem

- ❑ Bees are very discriminatory house hunters
 - ❖ Large enough to store honey for winter
 - ❖ Well ventilated for summers – they have not invented AC and electricity yet!
 - ❖ Insulated well enough for the winters – No heating either!
 - ❖ Close to perennial source of water
 - ❖ Protected from rains
 - ❖ Close to source of pollen
- ❑ Making it complex multi-variable solution
- ❑ They find the best solution almost 80 % of the time

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How do they Solve it

- ❑ Bees are tiny, their brains are smaller than the size of sand grain
- ❑ Have almost a million neurons in their brain.
 - ❖ Humans have more than 85 billion neurons
- ❑ They shake their bodies to select the possible solution
 - ❖ Biologist call it “wiggle dance”
- ❑ Hive mind :
 - ❖ Nature’s way to aggregate various perspectives and maximize collective wisdom
 - ❖ Swarms are dynamic, flexible
 - ❖ Discover option where majority agrees
- ❑ It makes them smarter and wiser
 - ❖ Humans get trapped in polls, votes, surveys which are polarizing and become heavily taxing
- ❑ Don’t feel bad!
 - ❖ Swarms have been doing it for 30 million years
 - ❖ Humans have been around for 200,000 years only
 - ❖ We will get there!

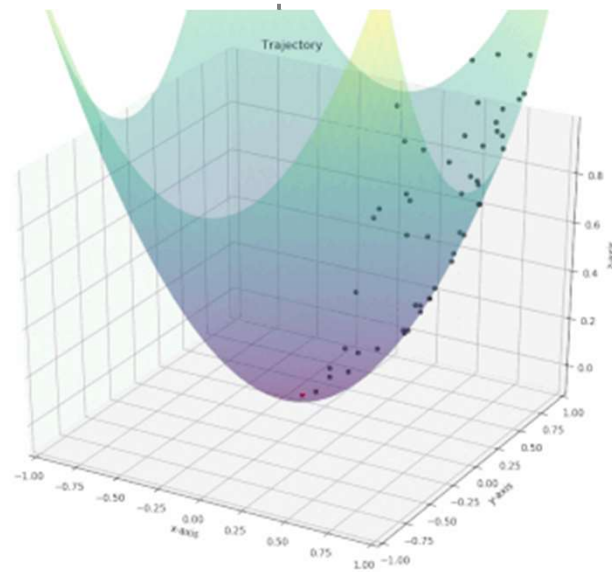
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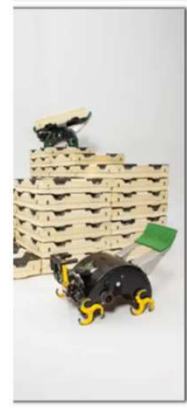
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Use cases

Collectiv



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Next Session...



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