

COMP 532
Machine Learning and
BioInspired Optimization
Lecture 2

Dr. Shan Luo
Department of Computer Science
shan.luo@liverpool.ac.uk

Parallel Problem Solving from Nature

- Introductory remarks
 - Setting the ground
 - Clarifications and definitions
- The power of natural systems
 - Massive parallel computation
 - Simple & elegant
- Intuitions of the techniques we will study

Parallel Problem Solving from Nature

- **Bio-inspired autonomous/learning systems**

are systems – software or robots – whose form (structure) and/or function (behavior) is based on biological principles and mechanisms, and are able to act under self-control

- **Multidisciplinary field**

That deals from the perspective of biology with various aspects of autonomy

- adaptability, functional and structural optimization, locomotion, sensory-motor control, mechanics, collective and swarm-type behavior, (co-)evolution, etc.

- a.k.a. **Artificial Life**

BioInspired systems v.s. Biosystems Modelling

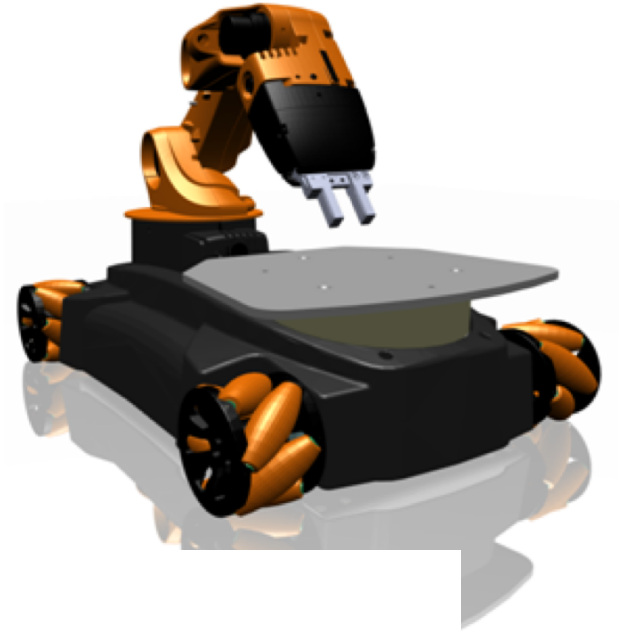
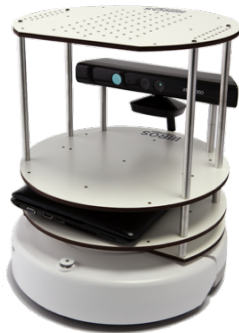
- **Bio-inspired systems:** Application of biological ideas to solve technological problems (“biomimetics”)
 - Different degrees of biological inspiration, drawn from different aspects of living degrees of biological inspiration, drawn from different aspects of living entities
 - Intentional disregard of biological details, biological ideas as a springboard for new design
 - Primary driving force: wish to build better artificial systems
- **Biosystems modeling:** use of technological systems as a modeling tool for addressing biological problems
 - Primary driving force: wish to better understand biological systems

Parallel Problem Solving from Nature



Example smARTLab – Robot Equipment

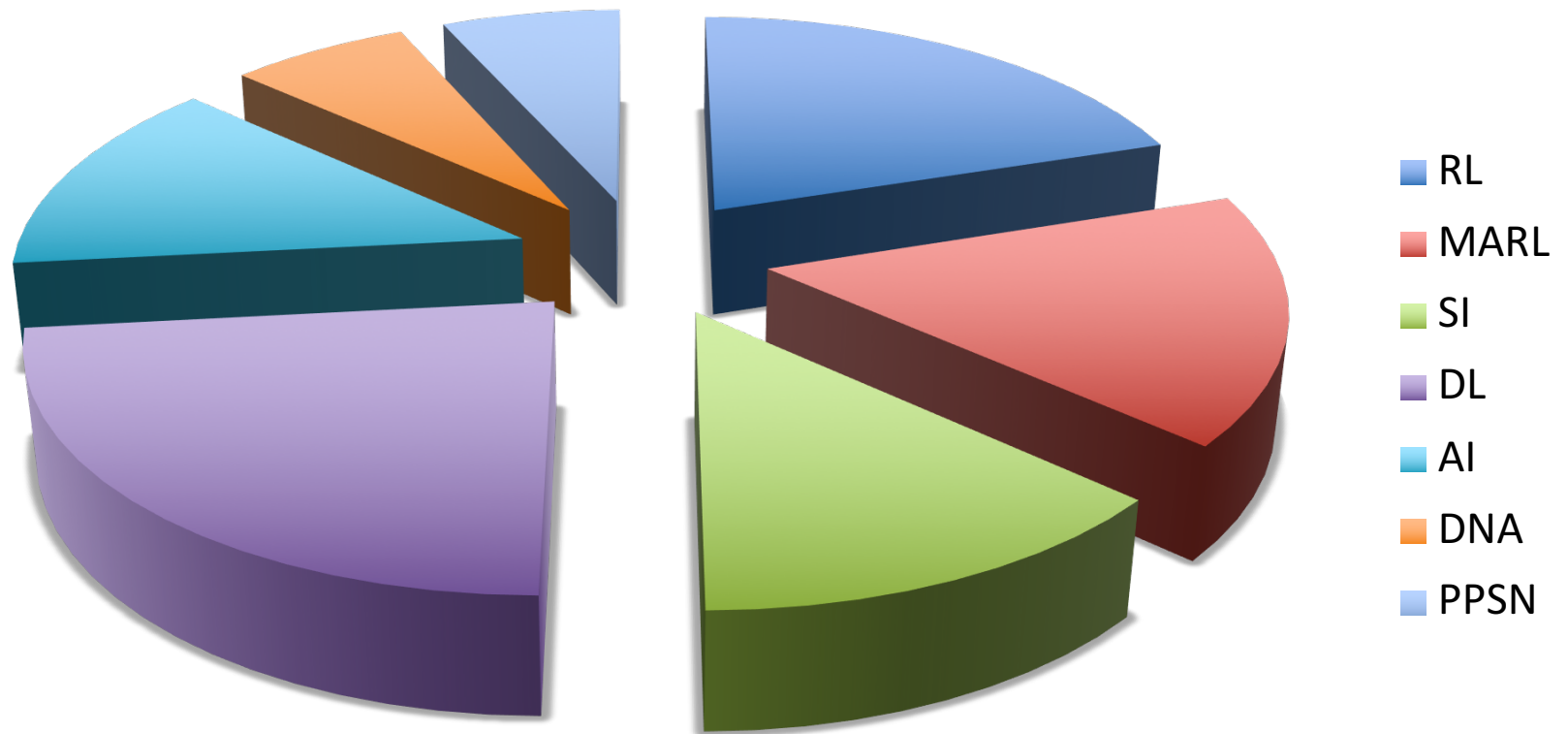
- 35x e-Pucks
- 20x Turtlebots (I and II)
- 1x Quadcopter
- 1x Octocopter
- 1x Telepresence robots
- 3x Kuka Youbot, robocup@work
- 6 crazieflies
- 3 Lisa nanocopters



Intuitions

(Definitions follow later)

Lectures

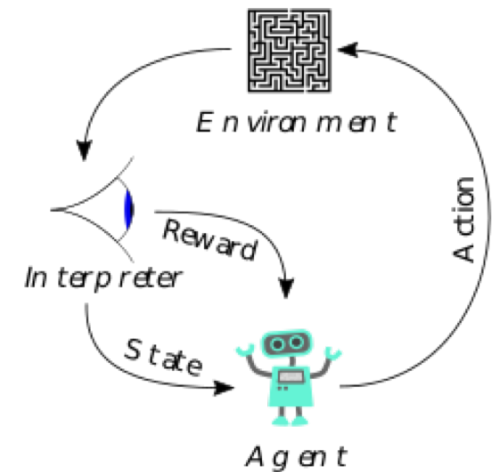
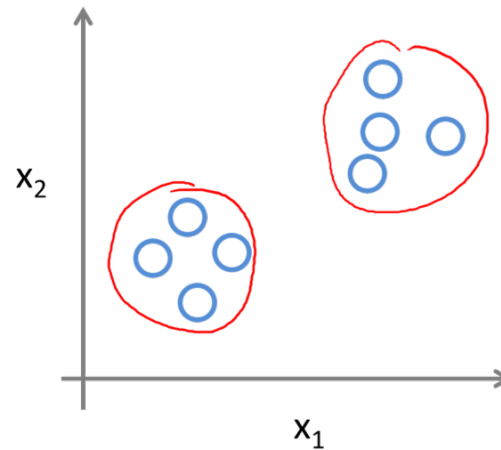
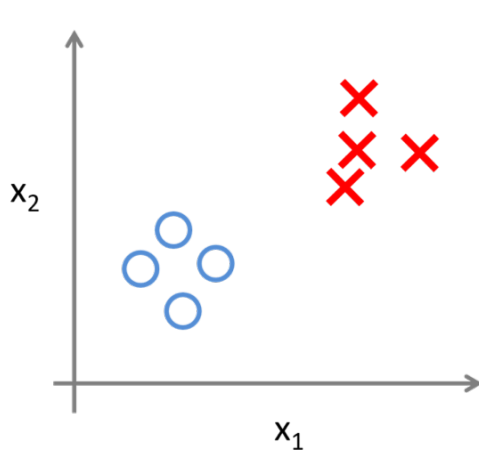


What is Reinforcement Learning?

- In reinforcement learning one **cannot ‘teach’** like in supervised learning
- Rather, learning from **interaction**, and
- **Guidance/advice**

What is Reinforcement Learning?

Supervised Learning	Unsupervised Learning	Reinforcement Learning
<ul style="list-style-type: none">• Labeled data• Direct feedback• Predict outcome/future	<ul style="list-style-type: none">• No labels• No feedback• “Find the hidden structure”	<ul style="list-style-type: none">• Decision process• Reward system• Learn series of actions



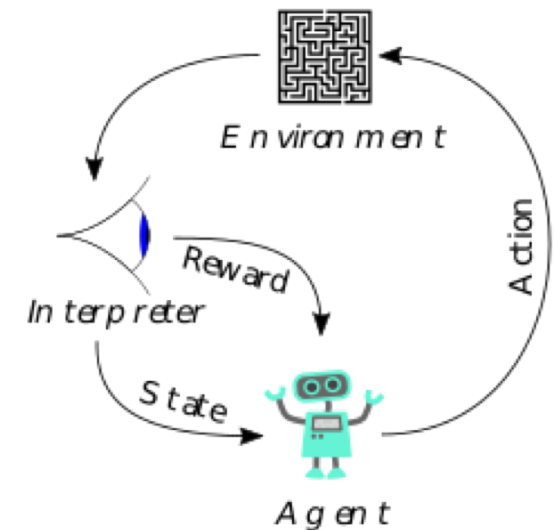
What is Reinforcement Learning?

Agent is interacting with **environment** observing some **state** and gaining **rewards**.

Problem: how to maximize cumulative reward?

Why is it difficult?

- Rewards can be delayed, positive and negative;
- State can give partial and noisy observations;
- Environment can be unknown a-priori and change over time;
- Result of actions can be stochastic.



RL: from intuition to artificial systems



The best RL'er we create so far!

RL: from intuition to artificial systems



What is Multi-agent Learning?

Multi-agent systems (MAS) are distributed systems of independent agents that cooperate or compete to achieve a certain objective.

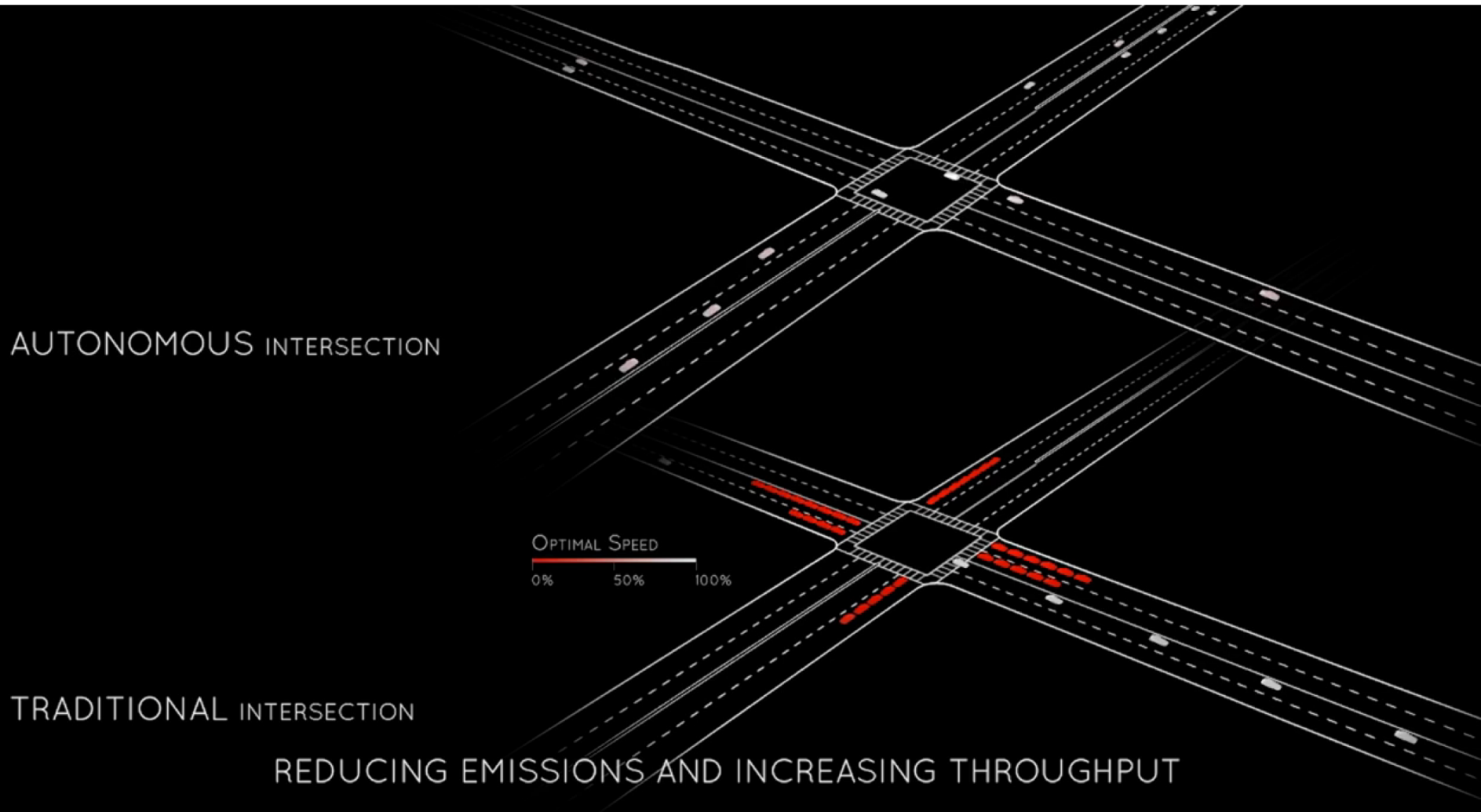
What is Multi-Agent Learning?

- Several paradigms for MAL
 - Swarm Intelligence
 - Evolutionary Computation
 - Reinforcement Learning
 - Evolutionary Game Theory
 - Learnable mechanism design

MAS: from intuition to artificial systems



MAS: from intuition to artificial systems



What is Swarm Intelligence?

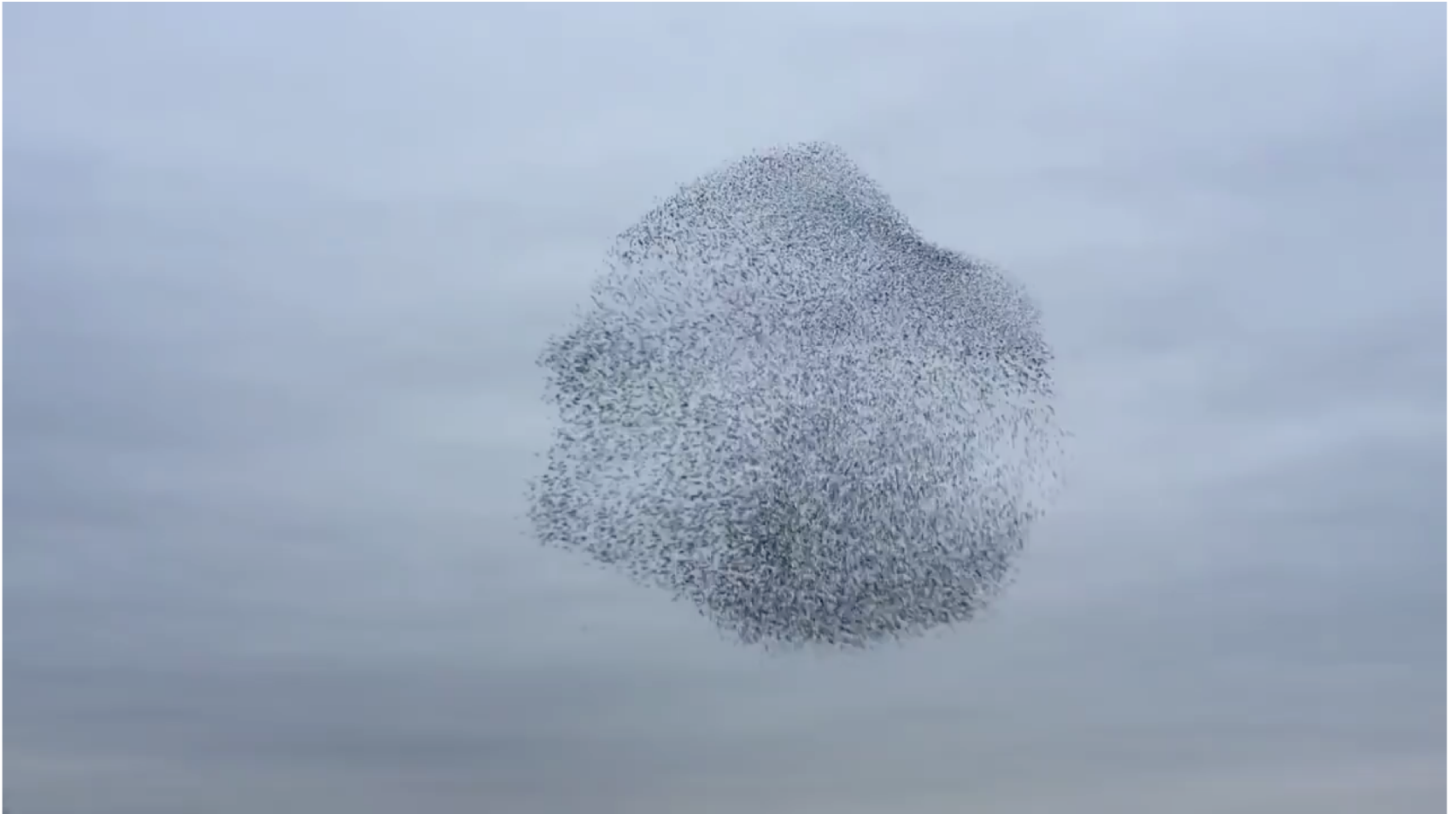
Swarm Intelligence (SI) is the **collective behaviour of decentralised, self-organised** systems, natural or artificial.

Collective >>> Individual

No leader

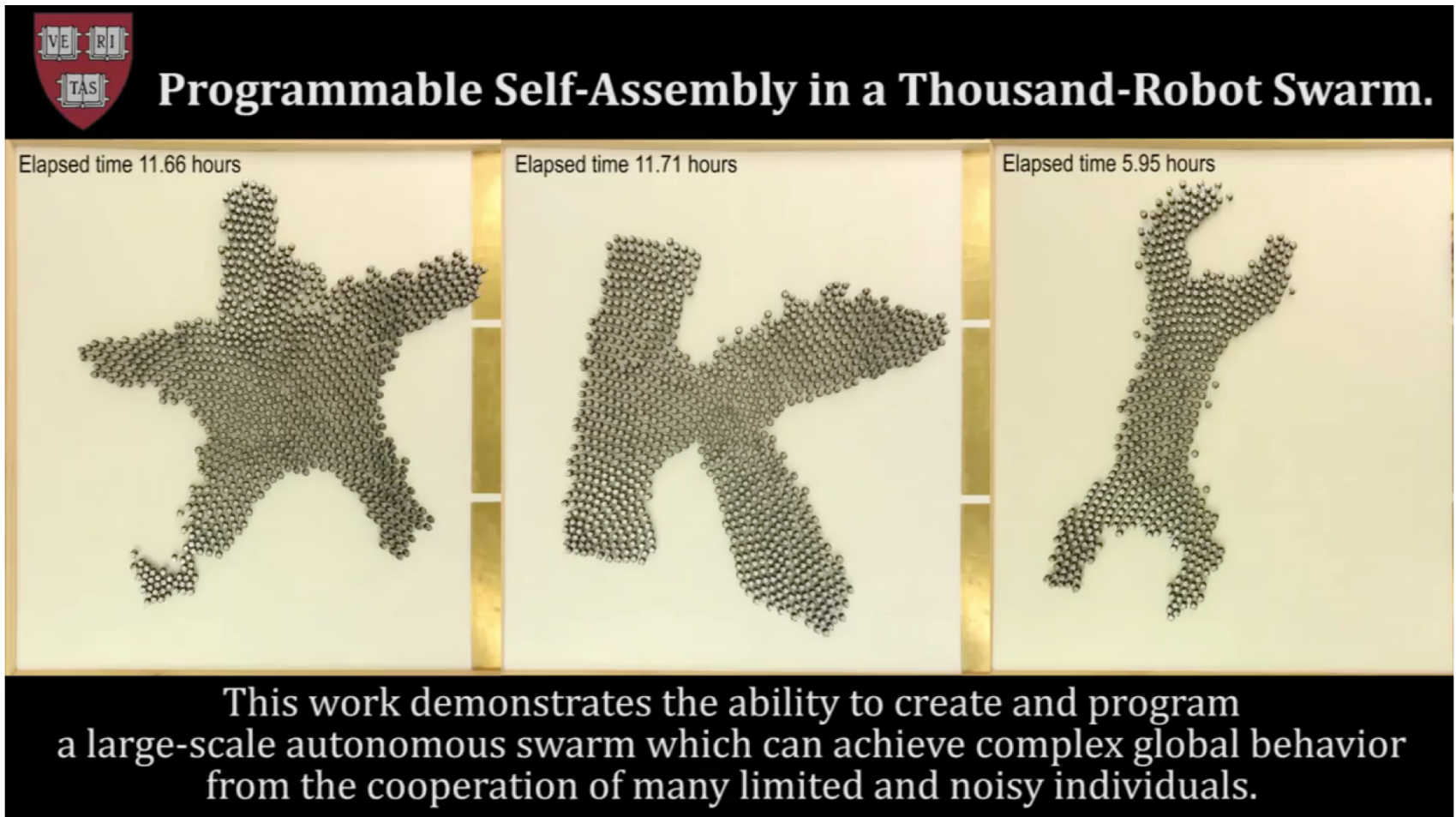
Simple Rules -> intelligence

SI: From intuition to artificial systems



<https://www.youtube.com/watch?v=eakKfY5aHmY>

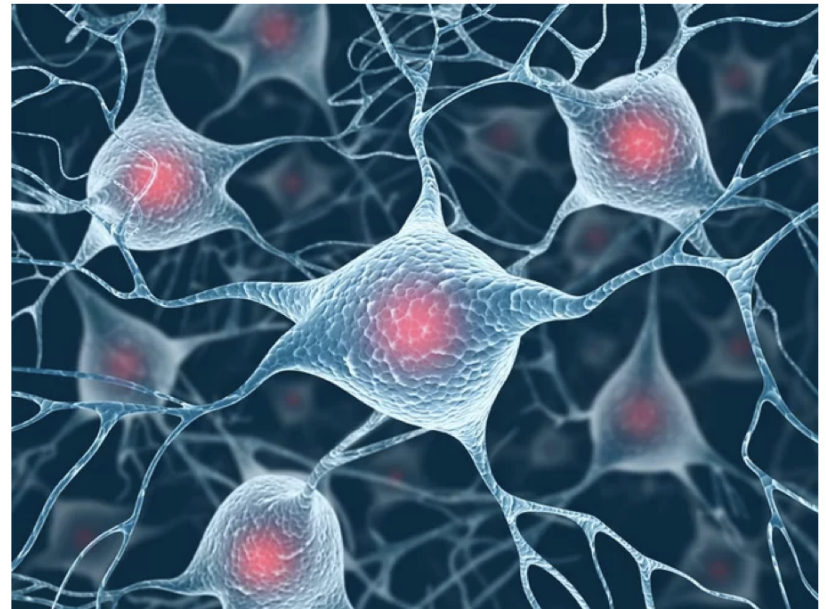
SI: From intuition to artificial systems



What is Deep Learning?

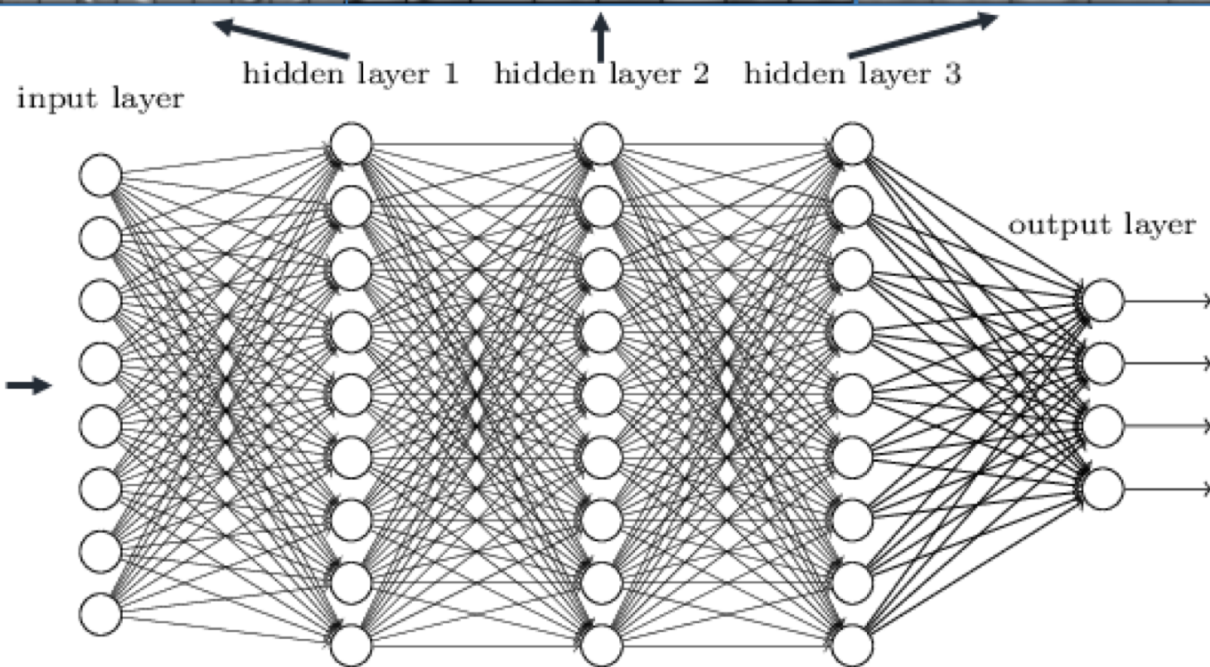
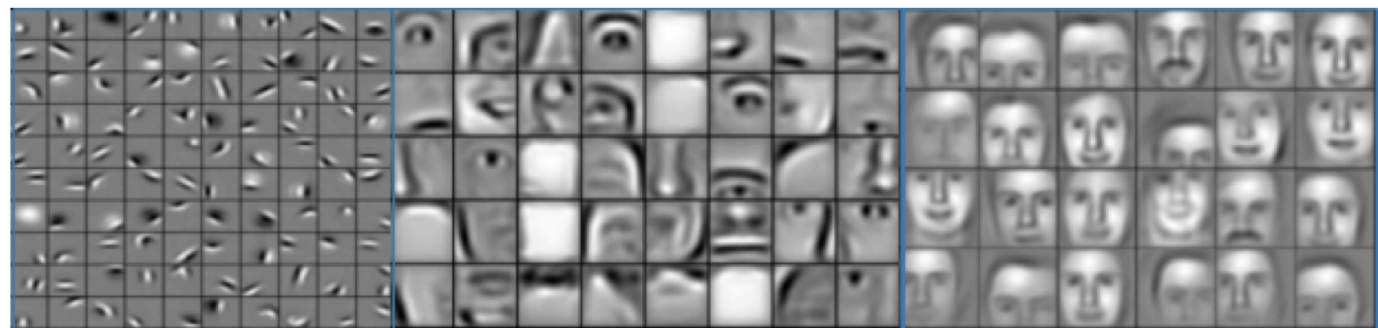
Deep learning has **networks** which are capable of **learning representations** from data.

DL: from intuition to artificial systems



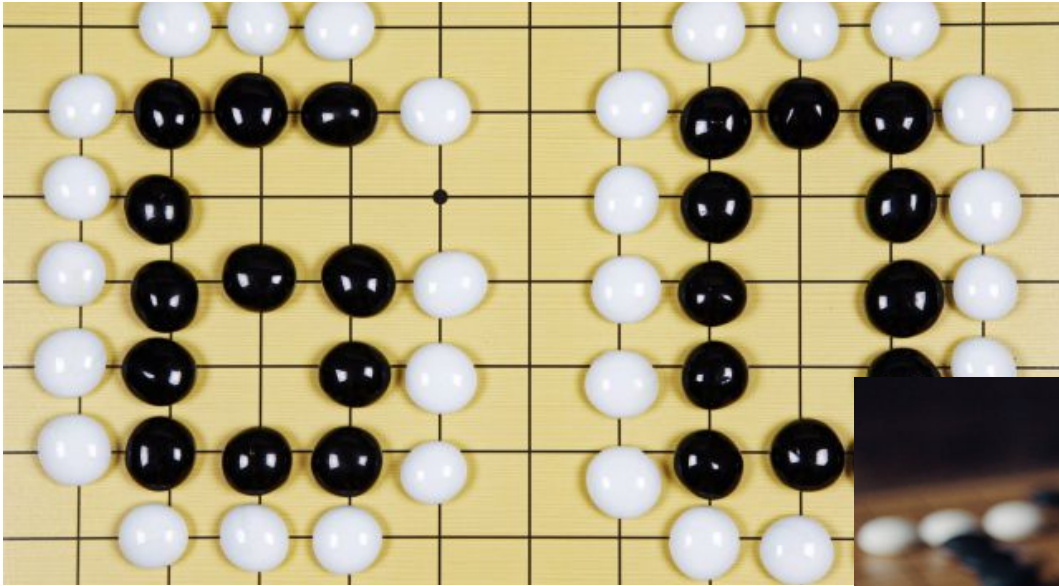
DL: from intuition to artificial systems

Deep neural networks learn hierarchical feature representations



DL: from intuition to artificial systems

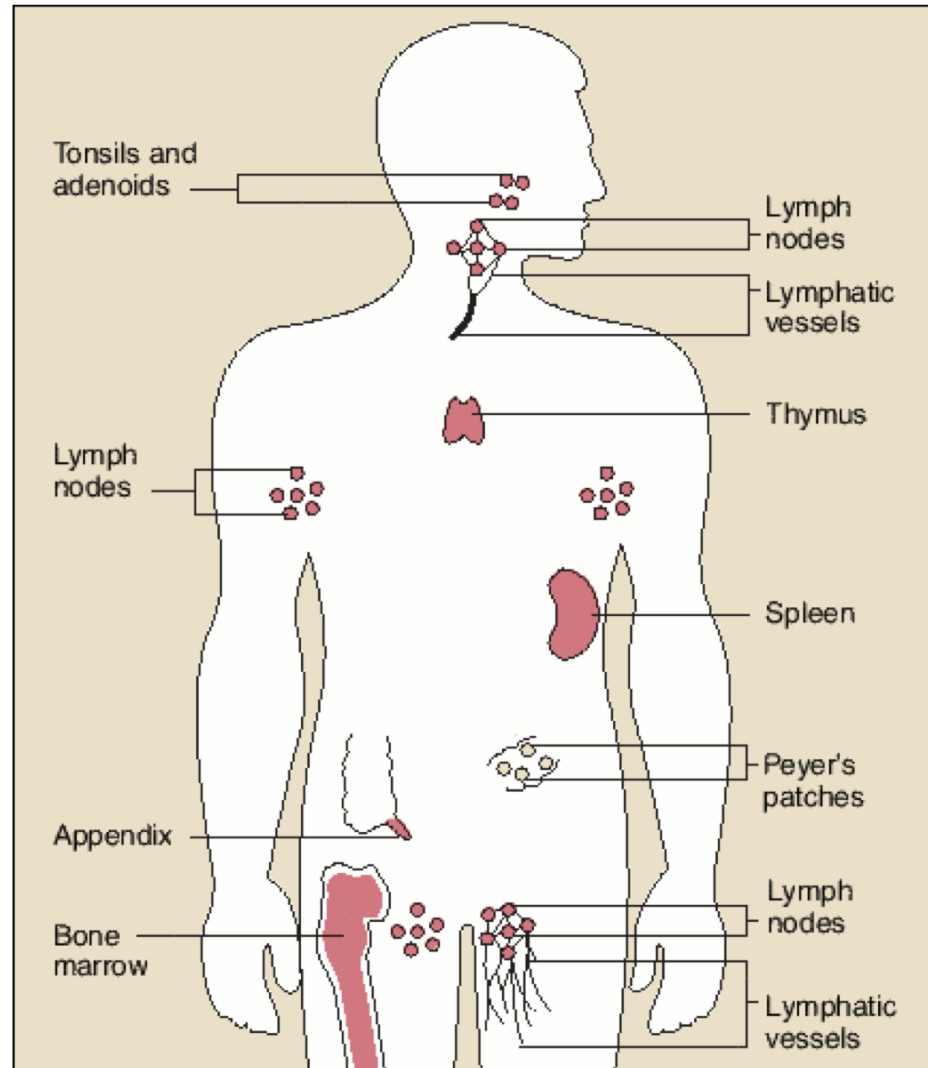
Google's Alpha-Go algorithm



What are Artificial Immune Systems?

Artificial Immune Systems (AIS) are adaptive systems inspired by theoretical immunology and observed immune functions, principles and models, which are applied to complex problem domains.

ALS: from intuition to artificial systems



AIIS: from intuition to artificial systems

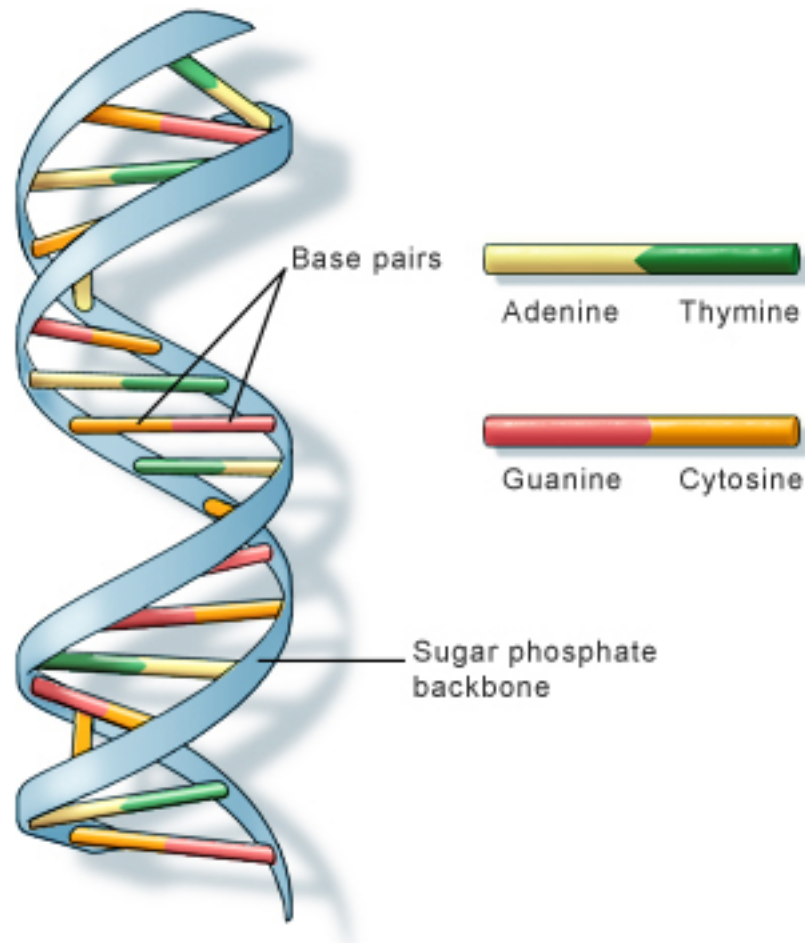


Computer virus detection

What is DNA Computing?

DNA computing is utilizing the property of DNA for **massively parallel computation**.

DNA: from intuition to artificial systems



DNA: from intuition to artificial systems



Summary

- Intuitions of BioInspired paradigms
- We will dive in the details next lesson
 - Reinforcement Learning