Can nature Inspire computing?

INSPIRATION FROM NATURE

Nature is full of examples in which agents show adaptive and cooperative behavior, directly or indirectly, to achieve certain goals

Some examples are:

- Cells, immune system, brain cells and DNA
- Ant Colonies, Bee Hives
- Swarms of Birds, fish
- Animals: lions, monkeys,..
- Human: collective behavior

Some algorithms in this course are inspired by these examples

SWARM INTELLIGENCE IN HONEYBEES

How bees use swarm intelligence to make decisions

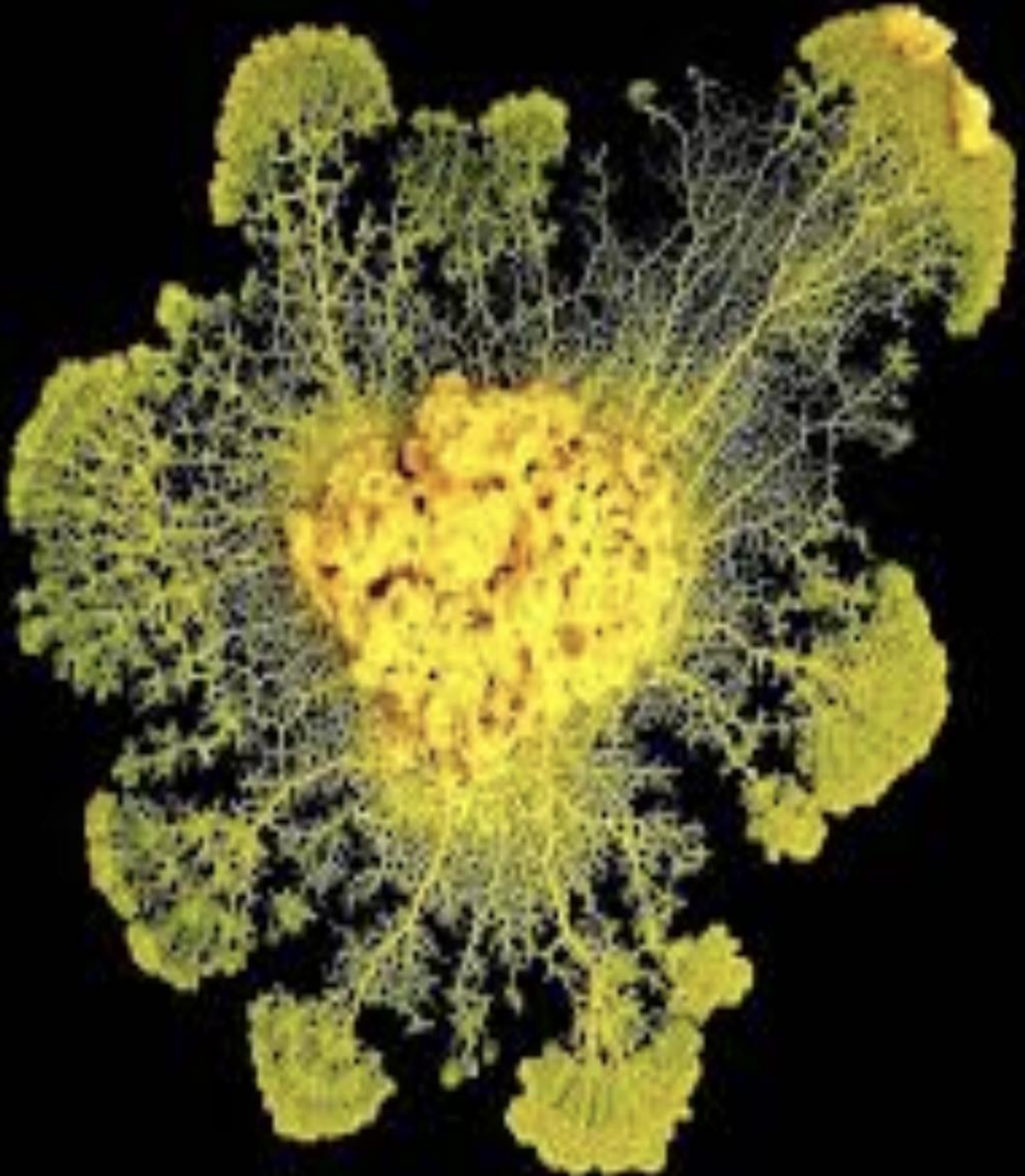
Amoeba or ameba are one-celled organisms belonging to the phylum Sarcodina of the kingdom Protista.

Slime Mold

Slime mold is a kind of colony of unicellular amoeba. It acts like a distributed system consisting of numbers of self-induced oscillators.

Searching Behavior of Slime Mold

When foodstuffs in the environment are exhausted, amoebae begin to aggregate, after which amoebae form multi-celled slugs.

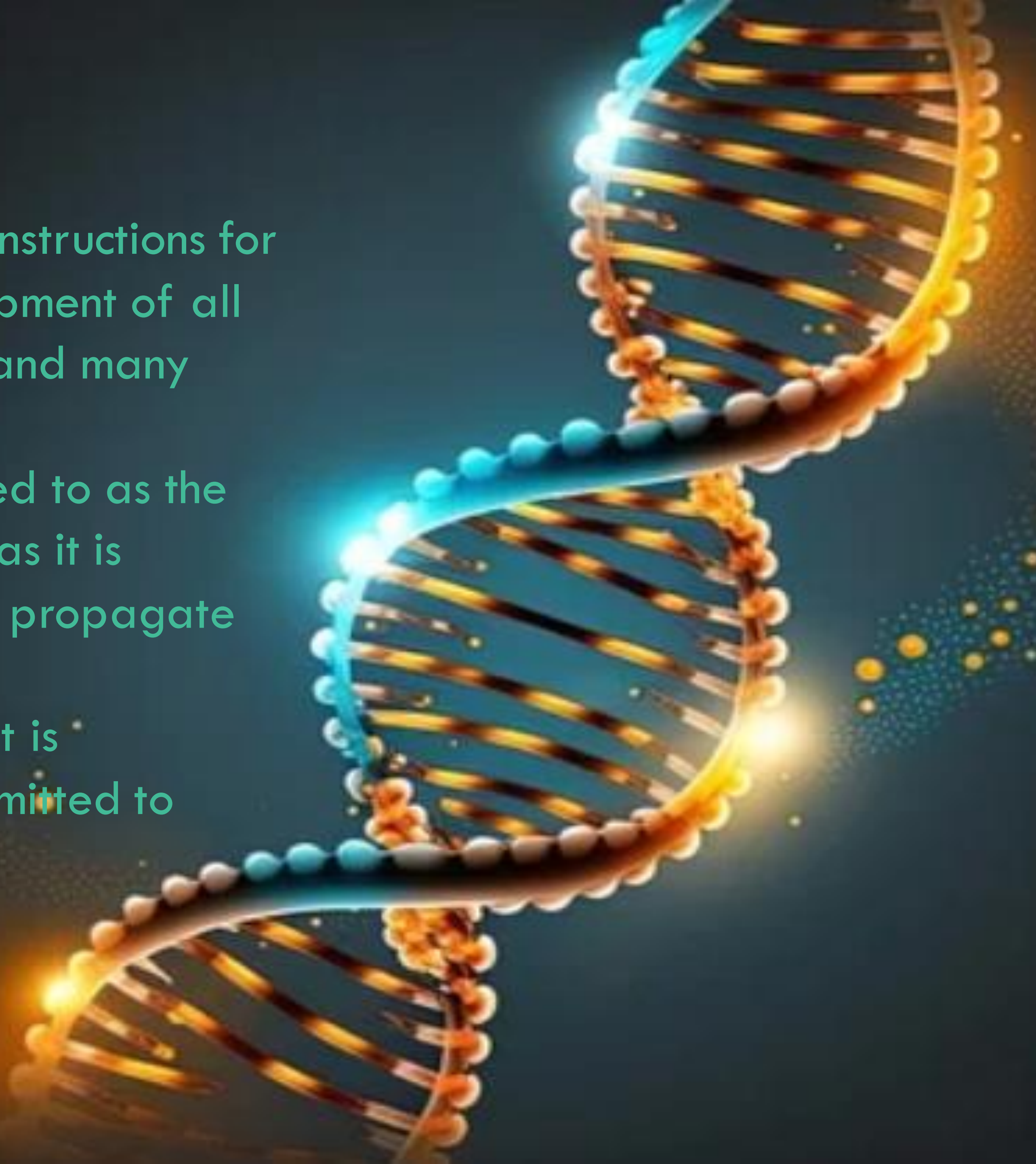


DNA

DNA carries generic instructions for the biological development of all cellular forms of life and many viruses.

It is sometimes referred to as the molecule of heredity as it is inherited and used to propagate traits.

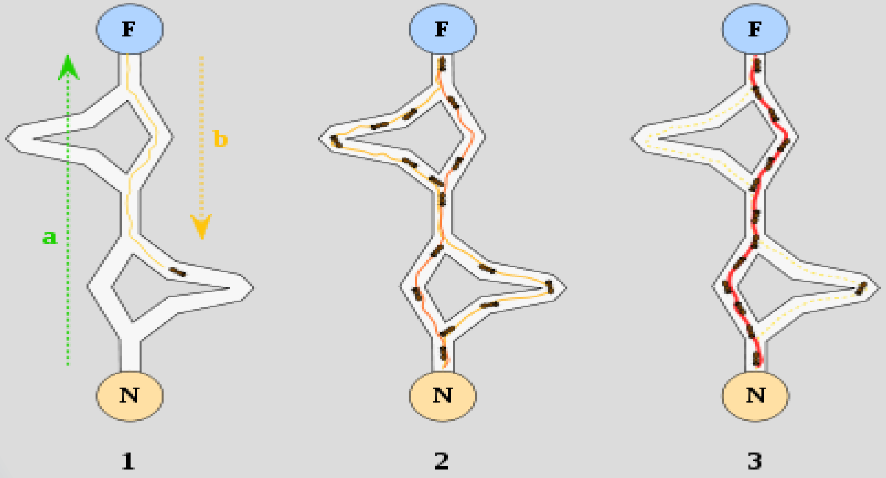
During reproduction, it is replicated and transmitted to offspring



ANTS AND BEES

Ants: about 10^{15} on earth

The total weight of ants is about the total weight of humans



Ants' agricultural behaviour (© Alex Wild)

SWARMS

Bird Flocking

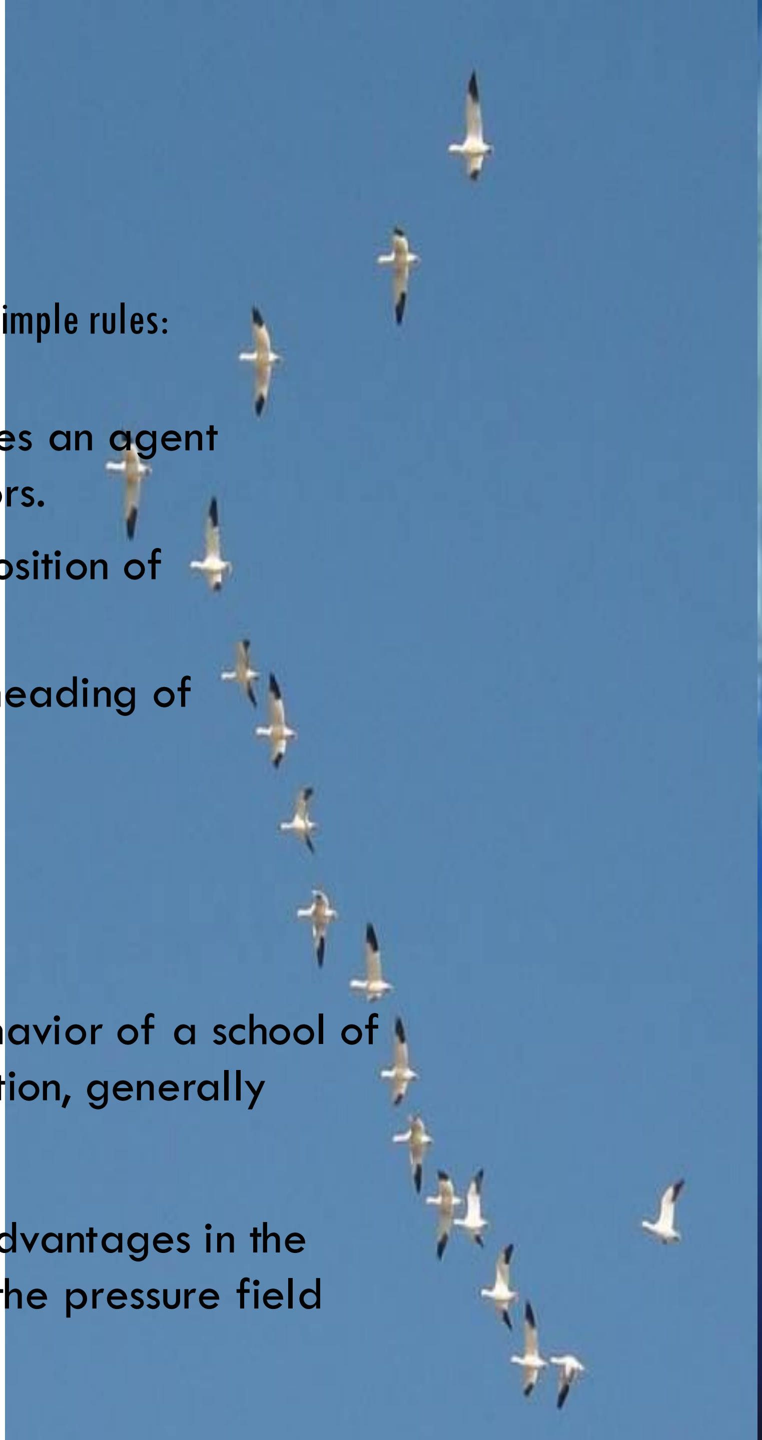
Staying together but not colliding

Bird flocking is a behavior controlled by three simple rules:

Separation is the behavior that causes an agent to steer away from all of its neighbors.

Cohesion - steer towards average position of neighbors

Alignment - steer towards average heading of neighbors



Fish Schooling

The term schooling describes the behavior of a school of fish of similar size and body orientation, generally cruising in the same direction

Cruising in a close group has advantages in the energy consumption, one fish utilizing the pressure field created by the next fish.

WHAT INTELLIGENT MACHINES CAN LEARN FROM A SCHOOL OF FISH

BEHAVIOR

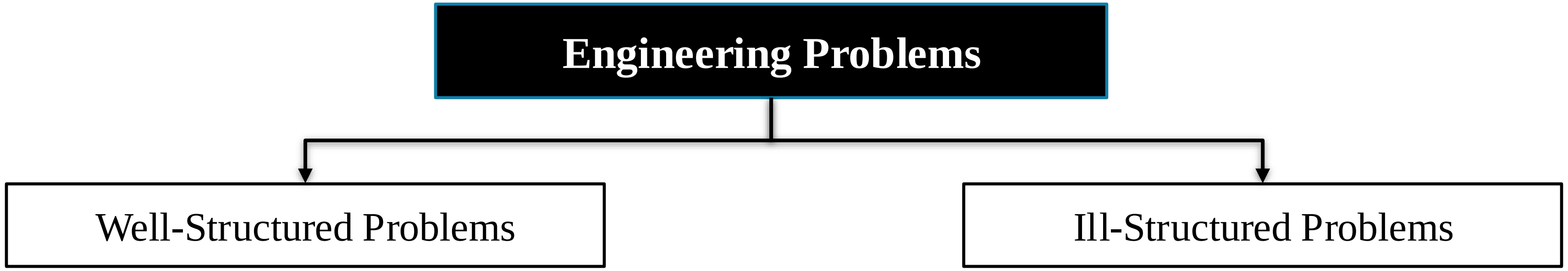
Behavior	Inspired Models/Algorithms	Applications
Bacterial Intelligence	Bacterial Chemotaxis Model, EC	Neural networks, robotic configurations
Chromosome behavior	Genetic Algorithm, EC	Optimization Problems in Distributed Computer Systems, Cooperative Manipulations
Ants	Ant Colony Optimization (ACO)/ AC clustering	Machine scheduling, Network Routing, Allocation and assignments, text classification and clustering, graph problems
Swarms	Particle Swarm Optimization (PSO)	Optimization problems, scheduling, mobile robots and control, neural network training,

SWARM ALGORITHM HISTORY

Name	Pioneer	Year	Inspiration
ACO	M. Dorigo	1992	Ant colonies
PSO	J. Kennedy	1995	Group of birds
ABC	D. Karaboga	2005	Honey bees
WASPCO	P. Pinto	2005	Wasp
TCO	M. Roth and S.Wicker	2003	Termite
BATCO	Xin-She Yang	2010	Bat
BFO	K. M. Passino	2002	E. Coli and M. Xanthus

Classes of Problems

REAL-WORLD PROBLEMS



WELL-STRUCTURED AND ILL-STRUCTURED PROBLEMS

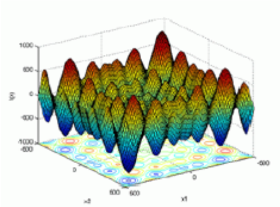
Well- Structured Problems: Problems for which the existing state and desired state are clearly identified, and the methods to reach the desired state are fairly obvious.

Ill-Structured Problems: Situation in which its existing state and the desired state are unclear and, hence, methods of reaching the desired state cannot be found.

	Well-Structured	Moderately-Structured	Ill-Structured
Goals	well defined	usually well defined	undefined
Beginning State	well defined	well defined	well defined
Actions	well defined	many possible actions	undefined
End State	well defined	well defined	undefined
Constraints	well defined	usually well defined	usually not well defined
Example	starting a car	fixing a car	designing a car

REAL-WORLD PROBLEMS

- Some Sources of Complexity
  - Multimodality



  - Lack of exact mathematical model

$$\min \quad \sum_{i,j} c_{ij} x_{ij}$$

$$\sum_i x_{ij} = 1 \quad \forall i, \qquad \sum_j x_{ij} = 1 \quad \forall j,$$

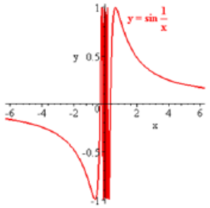
$$0 \le x_{ij} \le 1 \quad x_{ij} \ \text{integer},$$

$$u_1 = 1,$$

$$2 \le u_i \le n \quad \forall i \ne 1,$$

$$u_i - u_j + 1 \le (n-1)(1 - x_{ij}) \quad \forall i \ne 1, \forall j \ne 1.$$

  - Non-Differentiability

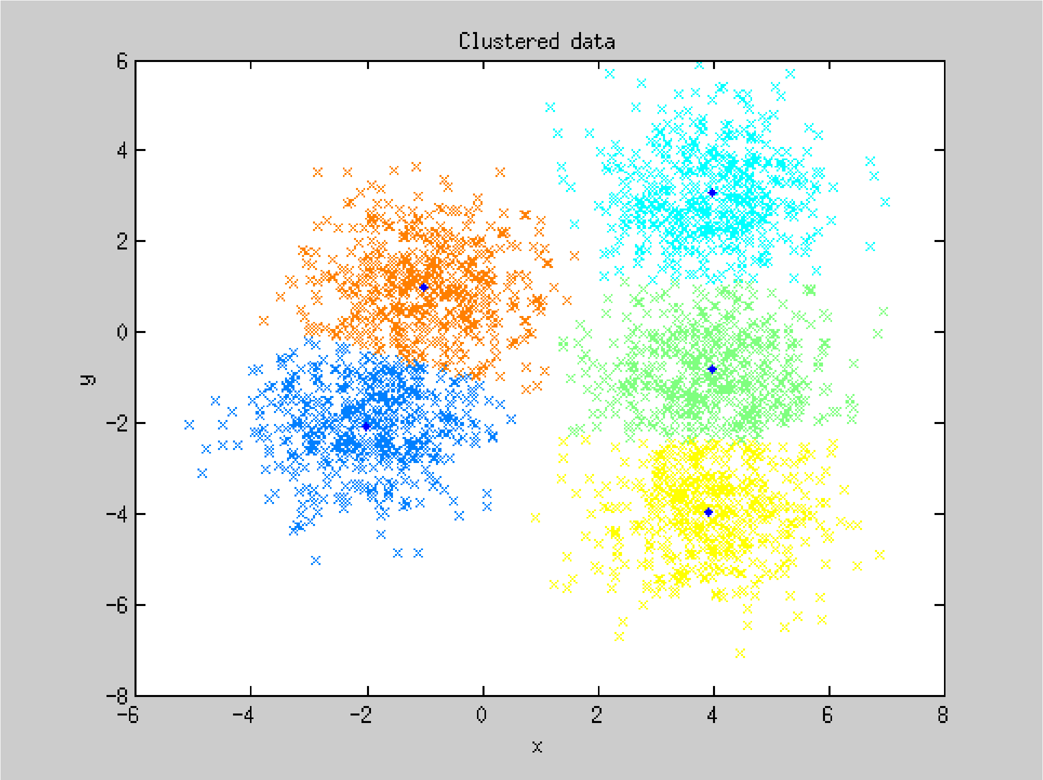


  - Combinatorial nature
  - Distributed nature

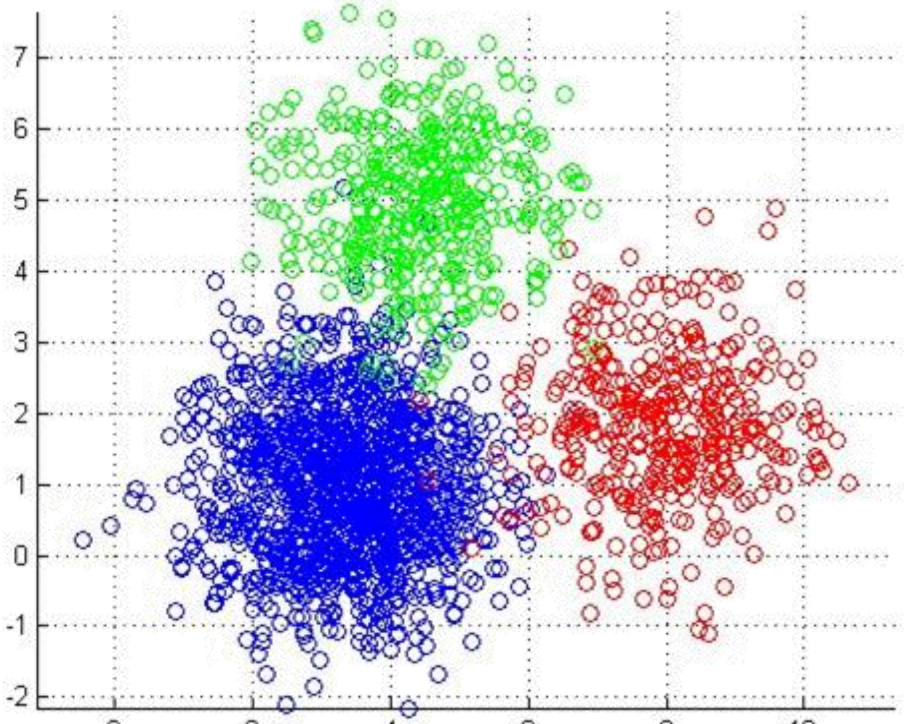
THE CLUSTERING PROBLEM

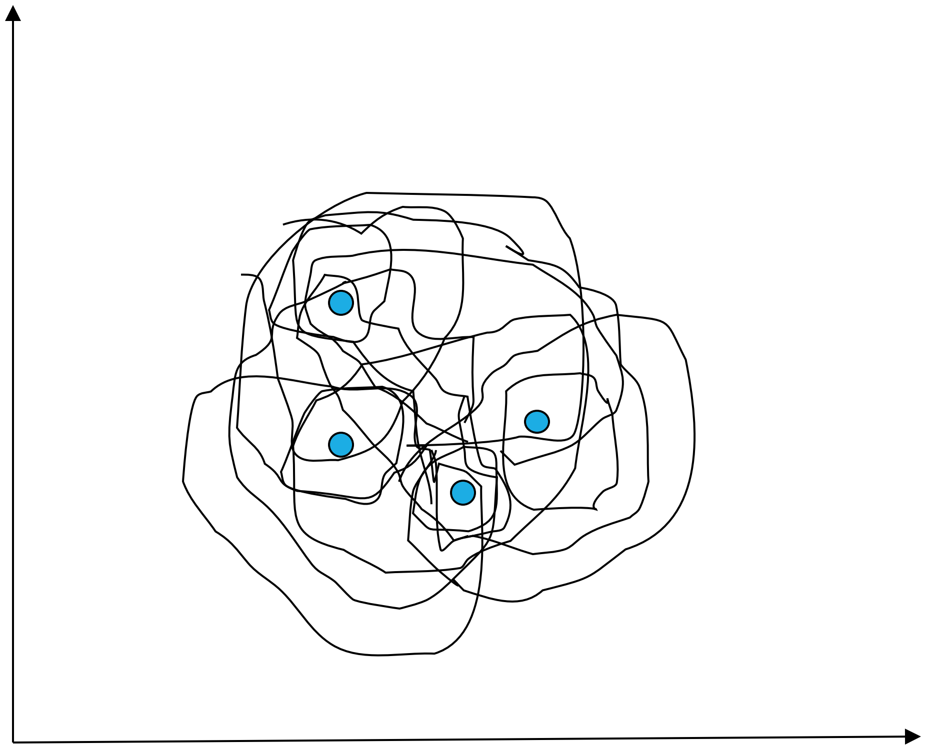
Given *n* objects, group them in *c* groups (Clusters) in such a way that all objects in a single group have a “natural" relation to one another, and objects not in the same group are somehow different

- Example of well-structured problem but practically ill-structured



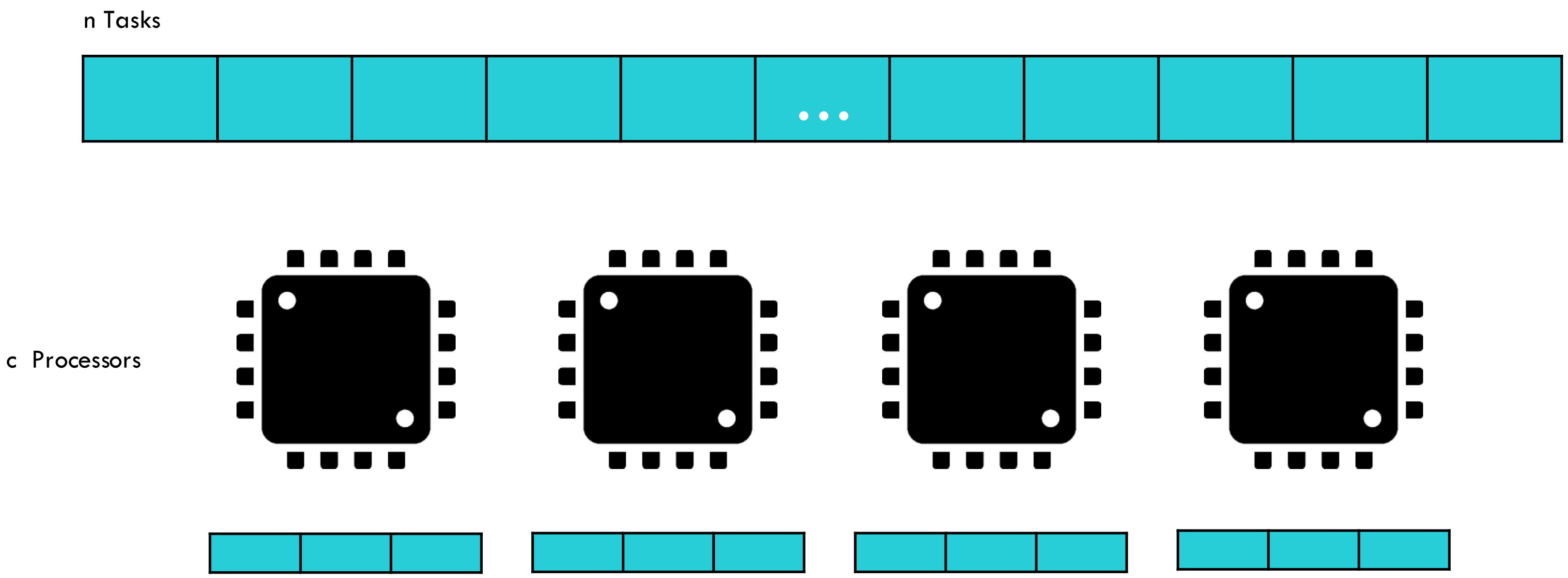
MANY WAYS TO CLUSTER OBJECTS





SET PARTITIONING

Set partitioning: a **partition** of a **set** is a grouping of the **set's** elements into non-empty subsets, in such a way that every element is included in one and only one of the subsets.



SET PARTITIONING

Number of possible partitions is given by:

$$\mathrm{N}(n,c) = \left(\frac{1}{c!}\right)\sum_{m=1}^{c}(-1)^{c-m}\binom{c}{m}m^{n}$$

If n = 50 and c = 4, the number is 5.3 x 10^{38}.

If n is increased to 100, the number becomes 6.7 x 10^{58}.

Enumerating all possible partitions for large problems is practically infeasible.

Sport Team Scheduling

SPORT TEAM SCHEDULING

31 teams

82 games

Team constraints

Arena constraints

189 days

Travel constraints

30 Arena

Other events

7 days/week

Channel viewing constraints

24 hours/day

POSSIBLE APPLICATIONS OF AI CONCEPTS

Game playing:
- Have well-defined rules with moves that can be searched intelligently.

Theorem proving:
- Proving correctness of this or that (e.g., circuits).

Path Planning

Robotics:
- Intelligent responses to some environment such as obstacle avoidance.

Pattern recognition,

Language processing,

And so forth…

- Complex problems are everywhere