# Introduction to Reinforced Learning

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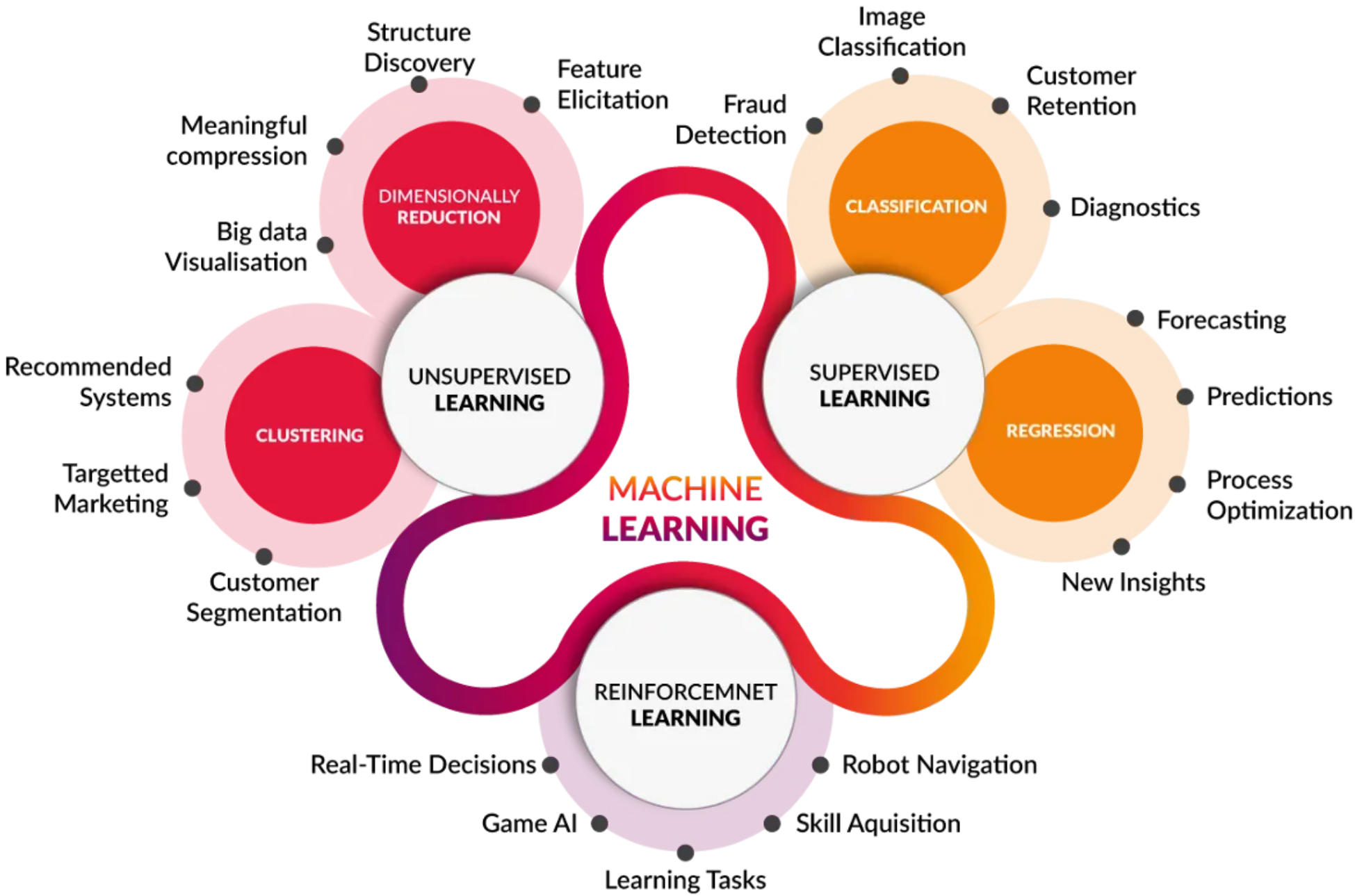
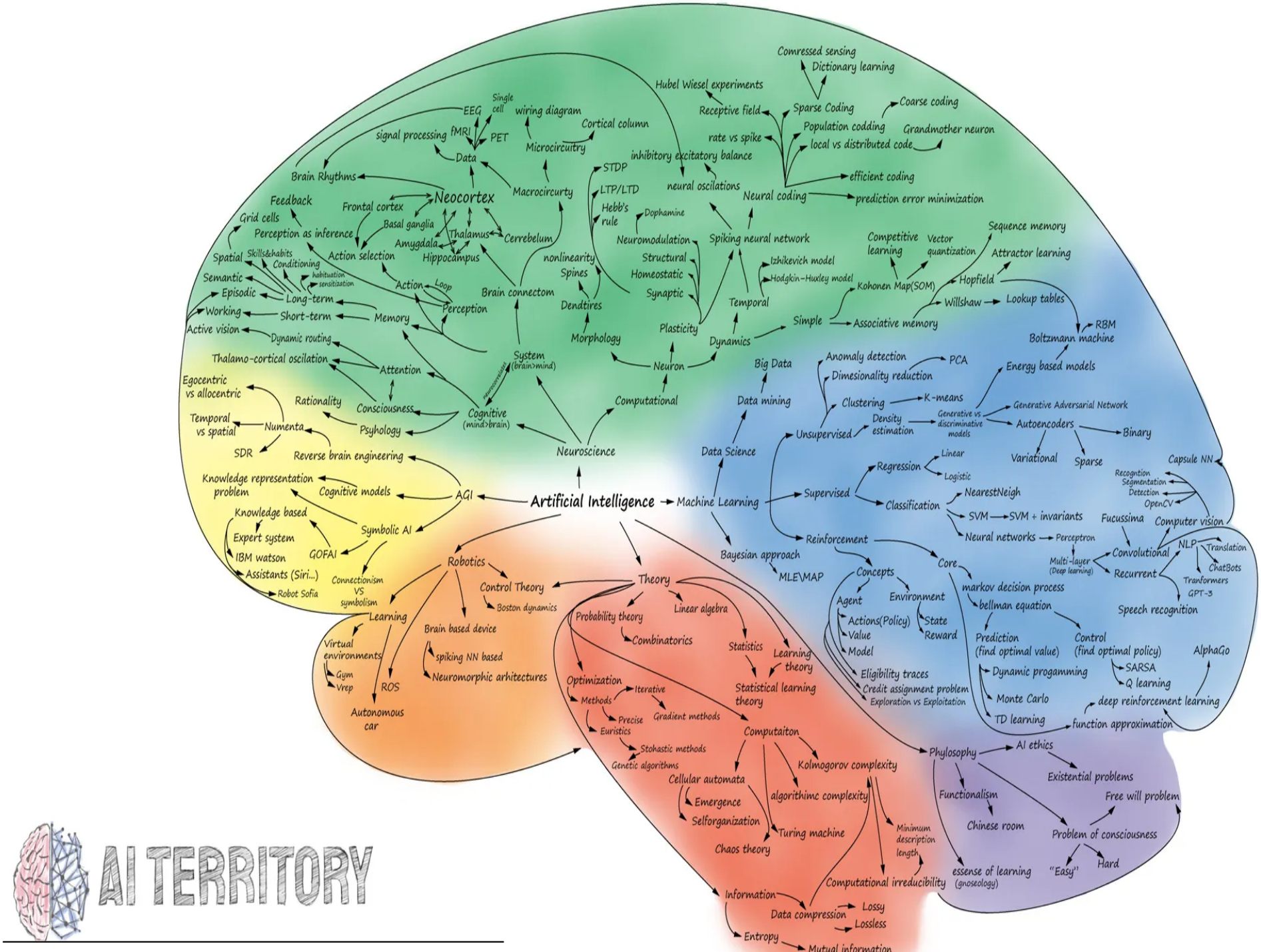
# Outline

# What is it?

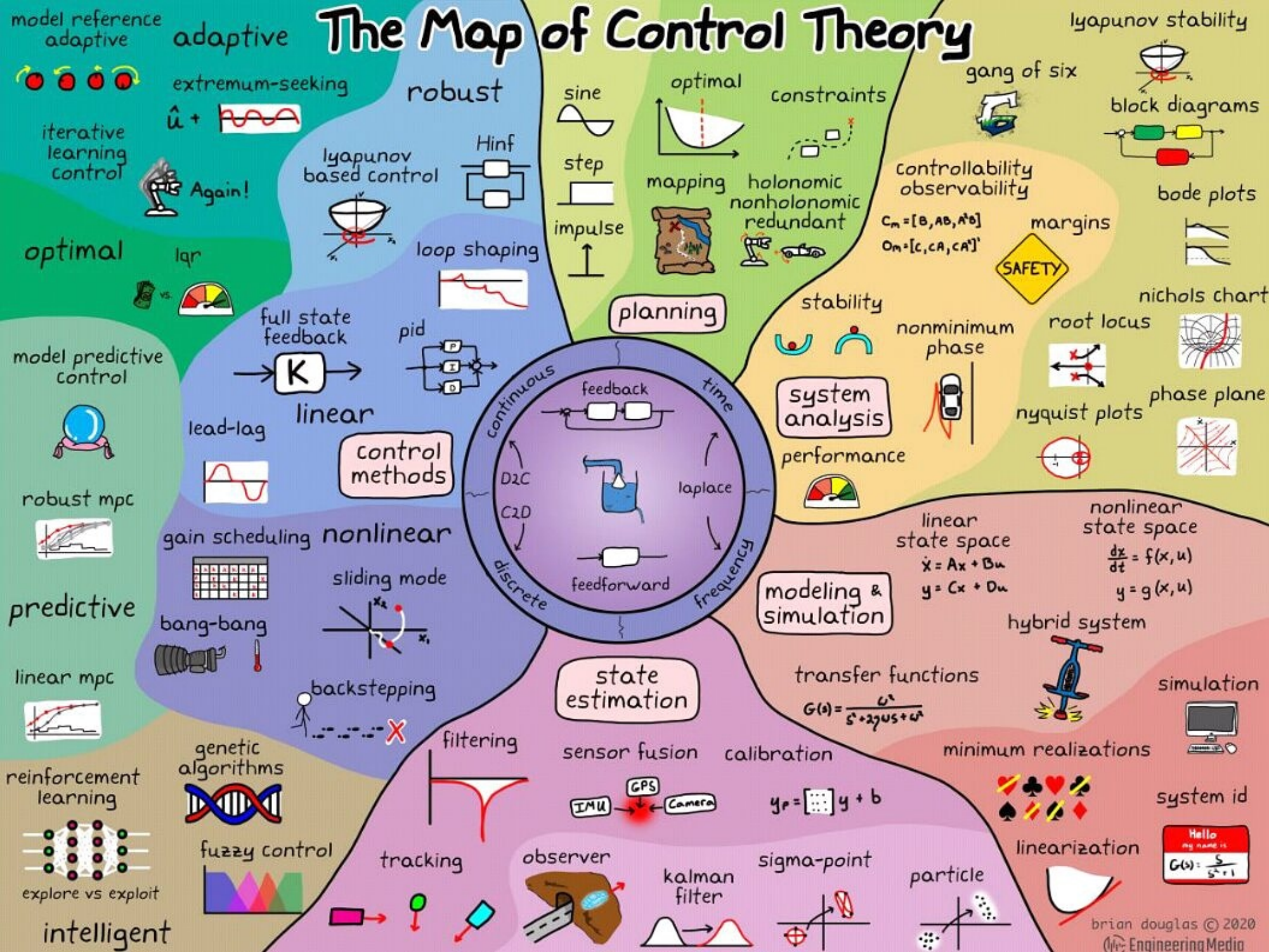



Adopted from https://becominghuman.ai/a-simple-way-to-explain-how-machines-learn-7d9155ac8bed



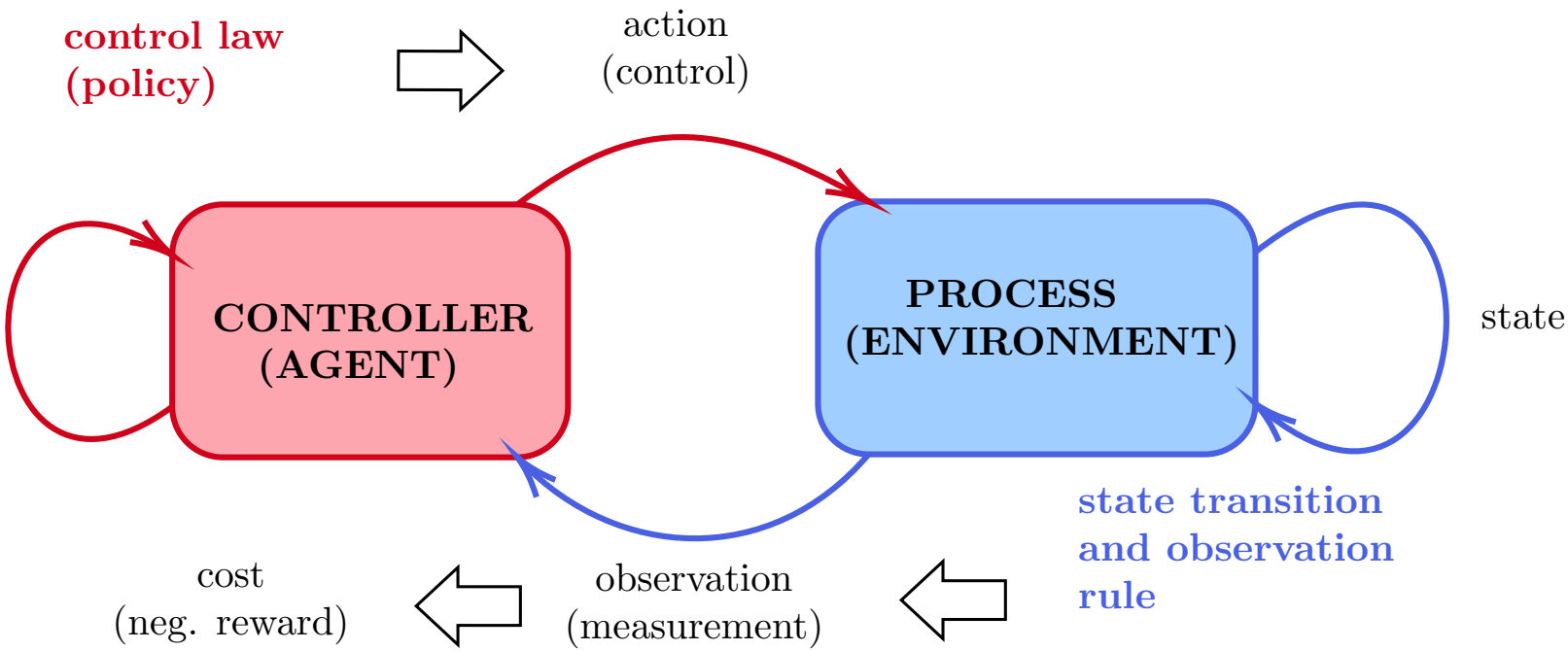

Adopted from https://medium.com/swlh/the-map-of-artificial-intelligence-2020-2c4f446f4e43

# The Map of Control Theory



# What is Reinforcement Learning?

RL is a framework for sequential decision making.



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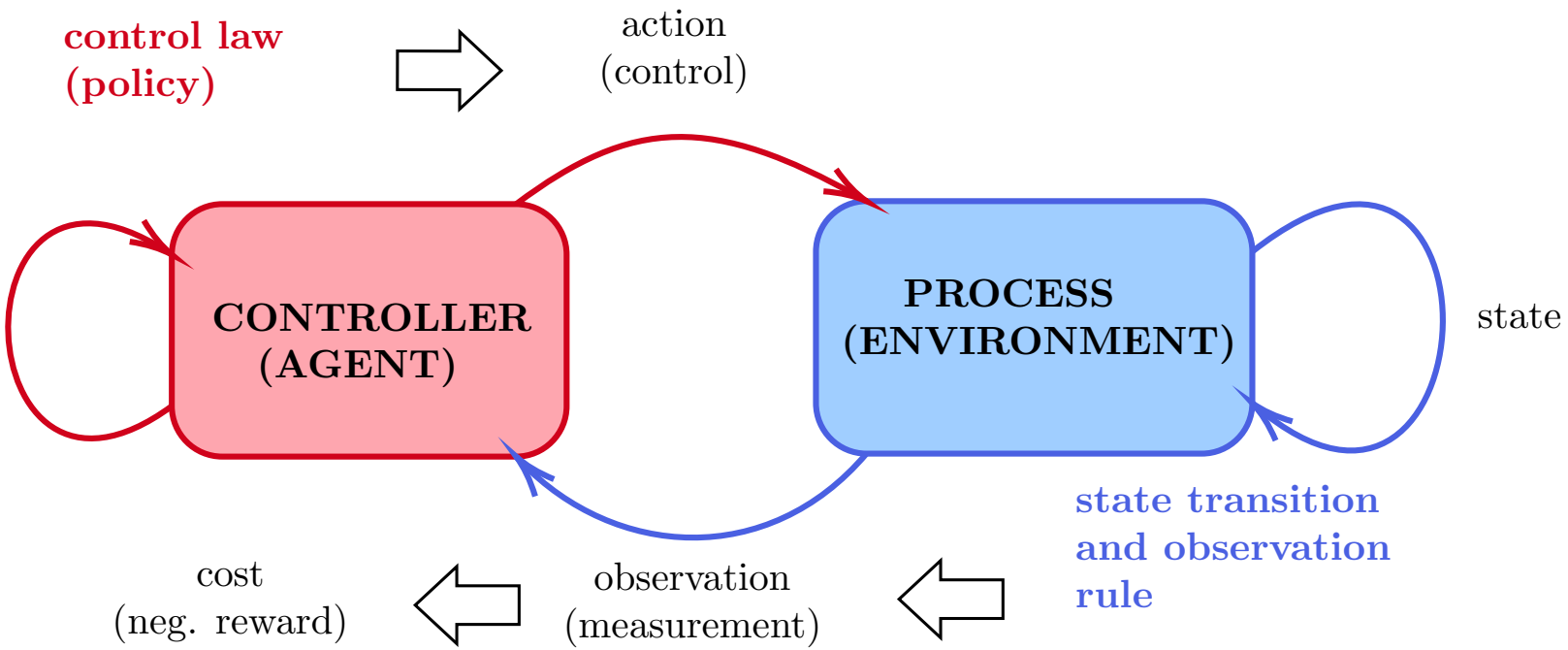



**Reinforcement Learning** is

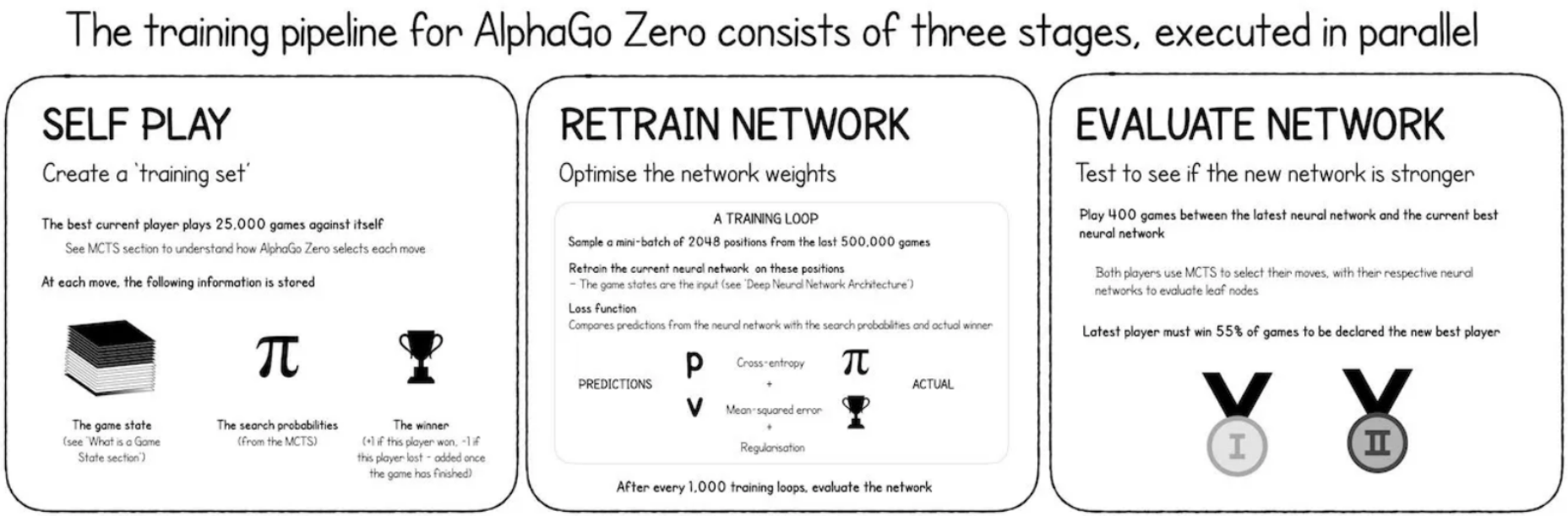
a model-free framework for solving optimal control problems stated as **Markov Decision Processes** (MDPs).

# Where is it applied?

# Selected Application: Go RL Go!

## ... or how RL reappeared in headlines

In 2016, the computer program **AlphaGo** captured the world's attention when it defeated the legendary Go player Lee Sedol. The ancient board game of Go is one of the most complex games ever devised, *with more possible board configurations than atoms in the universe*. It was a longstanding grand challenge for artificial intelligence and AlphaGo's 4-1 win was considered by many to be a decade ahead of its time. The system was invented by **DeepMind**, co-founded by scientist Demis Hassabis. Five months earlier, AlphaGo had beaten European champion Fan Hui, becoming *the first program to defeat a professional player*.




https://medium.com/applied-data-science/alphago-zero-explained-in-one-diagram-365f5abf67e0

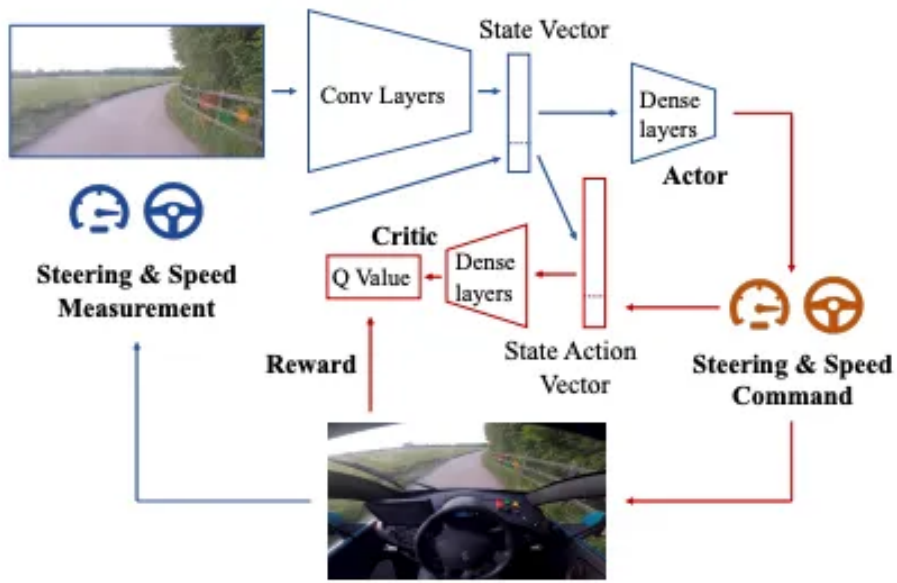
# Selected Application: Autonomous Driving

## Learning to drive in a day

In 2018 RL was used to train an agent to drive from scratch.

The agent was able to both drive and navigate successfully.

The agent was **later also successfully tested in the field**.

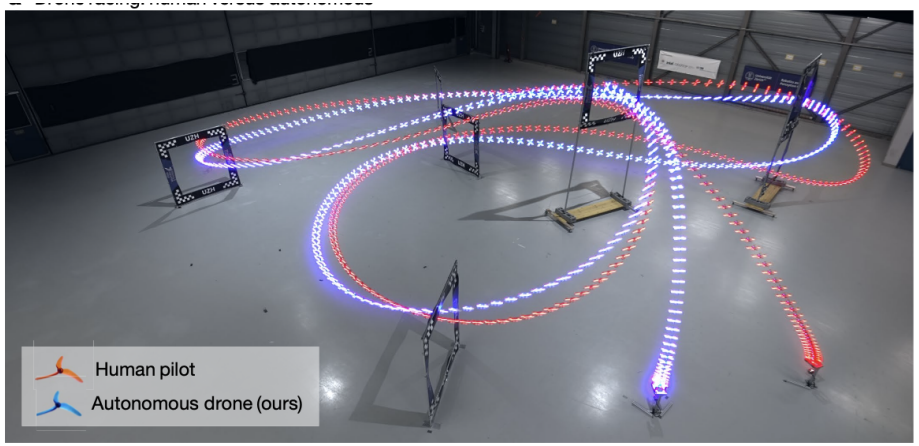



The original paper is freely available, and can be found here. Further discussion can be found here and in the following video.

# Selected Application: Drone Racing

## Going head-to-head against a champion...

First-person view (FPV) drone racing is a televised sport in which professional competitors pilot high-speed aircraft through a 3D circuit. Each pilot sees the environment from the perspective of their drone by means of video streamed from an onboard camera.




In 2013, a group of researchers from Zurich introduced **Swift** – an autonomous system that can race physical vehicles at the level of the human world champions.

Swift uses deep Reinforcement Learning agent trained using a combination of simulated data and data collected from the physical world.

The original paper can be accessed using here.

# Further Reading

... including lists of some potentially interesting applications

Interesting recent review articles:
[Li, 2018]
[Arulkumaran et al., 2017]
[Nian et al., 2020]

An excellent and very popular reference [Sutton and Barto, 2018].

Some other informative resources:
*Medium*: 9 Awesome Applications of Reinforcement Learning
*Medium*: RL Applications

# Selling Points

# Some properties of RL I

If I wanted to **sell** RL to you, I would say that:

- RL is general. It can uniformly handle
  - processes of strongly nonlinear and/or stochastic dynamics;
  - time-varying processes;
  - arbitrarily complex cost functions (performance indices).
- RL is model-free. It does not require explicit model of system dynamics, or even an explicit expression for the cost.
- RL inherently operates in discrete time – it can be directly implemented on a digital computer.

# Some properties of RL II

If I wanted to **sell** RL to you, I would say that:

- RL provides an alternative perspective to, and widens areas of application of much of the modern control theory.
- RL provides a direct link between control theory and artificial intelligence, in two ways:
  - It enables systematic applications of AI methods within control system design;
  - It highlights a methodology enabling application of control theory to many demanding applications – traditionally in the AI domain;
- RL provides a direct link between control theory and game theory, multi-agent systems theory, etc.

# References I



Arulkumaran, K., Deisenroth, M. P., Brundage, M., and Bharath, A. A. (2017).
Deep reinforcement learning: A brief survey.
*IEEE Signal Processing Magazine*, 34(6):26–38.


Li, Y. (2018).
Deep reinforcement learning: An overview.


Nian, R., Liu, J., and Huang, B. (2020).
A review on reinforcement learning: Introduction and applications in industrial process control.
*Computers & Chemical Engineering*, 139:106886.


Sutton, R. S. and Barto, A. G. (2018).
*Reinforcement Learning: An Introduction*.
The MIT Press, second edition.