

# Decision Under Uncertainty

An introduction

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# Last improvement in Artificial Intelligence

- ▶ *Nov. 2007*, Carnegie-Mellon win the Darpa Urban Challenge (2M\$)
- ▶ *Oct. 2015*, First release of Tesla Autopilot



- ▶ *Oct. 2015*, Victory of d'AlphaGo over professional player



# Last improvement in Artificial Intelligence

In France:

- ▶ *March 2018*, Rapport Villani - [www.aiforhumanity.fr](http://www.aiforhumanity.fr) -

# Our topic: Autonomous Decision Making

- ▶ Model the capability of actions
- ▶ Learn action interest
- ▶ Optimize policies of actions
- ▶ Handle large problem with optimization techniques

# The notion of complexity (Go)

GO:  $10^{170}$  positions,  $10^{600}$  games (chess:  $10^{120}$  games)



# The notion of complexity (Go)

**A classical 3 GHz computer:**  $3 \times 10^9$  op. per second  
 $\rightarrow 2.6 \times 10^{14}$  op. a day  $\rightarrow 10^{17}$  op. a year

**Enumerating all games:**  $O(n)$  with  $n = 10^{600}$ : arround  $10^{583}$  years.  
 $\rightarrow$  requires decomposed model and statistics...

**Sun life:** arround  $10^{30}$  years

# Decision Making Problem

**How to compute optimal appropriate responses  
to control dynamic systems ?**

**Knowing that:**

- ▶ Model could require very large exploration
- ▶ We potentially do not have the model
- ▶ Evolutions are generally uncertain

# Introduction to Decision Under Uncertainty

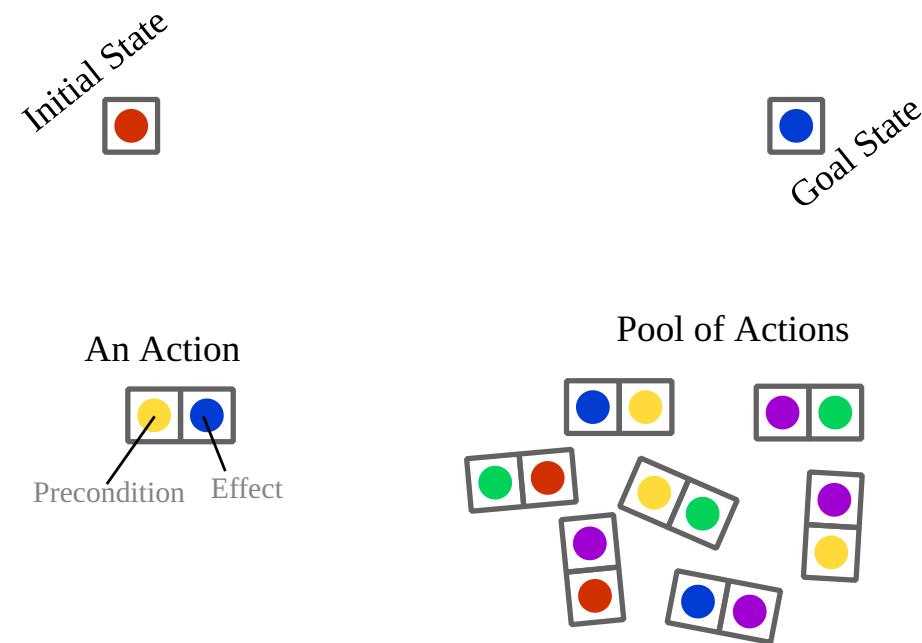
Is an introduction to models and algorithms to perform decision-making at a time step  $t$ , by considering potential effects.

- ▶ 19 hours (5 sessions)
- ▶ Mainly as tutorials
  - Simple dice games as a playground
  - Strategic 2-players games

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1. Introduction
  2. Class of problems
  3. The notion of Agent
  4. Decision Making Process of an Agent
  5. An Agent for the 421 games

# Class of problems - Deterministic Planning

Determining *a succession of actions* to drive a system from an initial state to a target state.

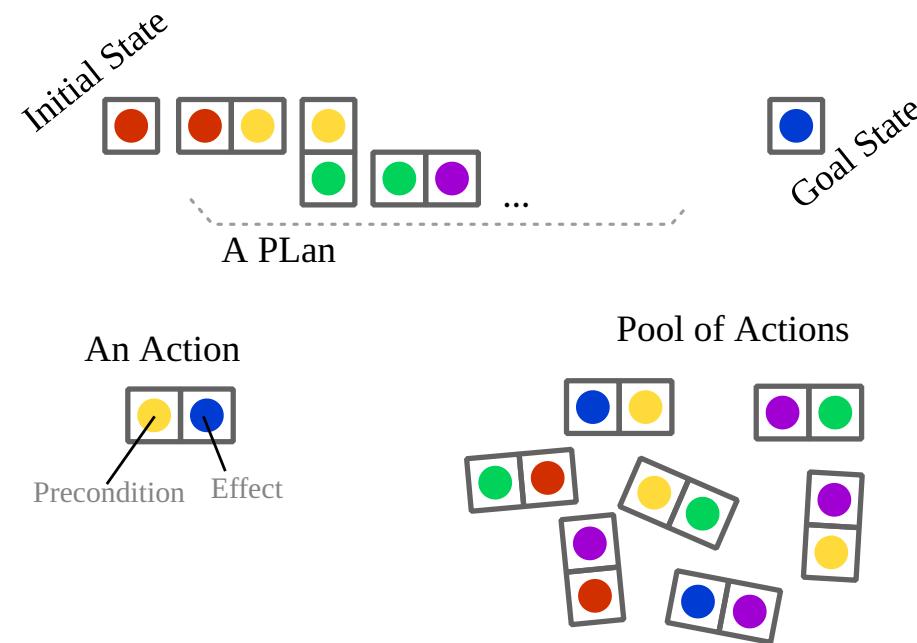


## Deterministic case:

- ▶ the effects, by doing an action, from a specific state is certain.

# Class of problems - Deterministic Planning

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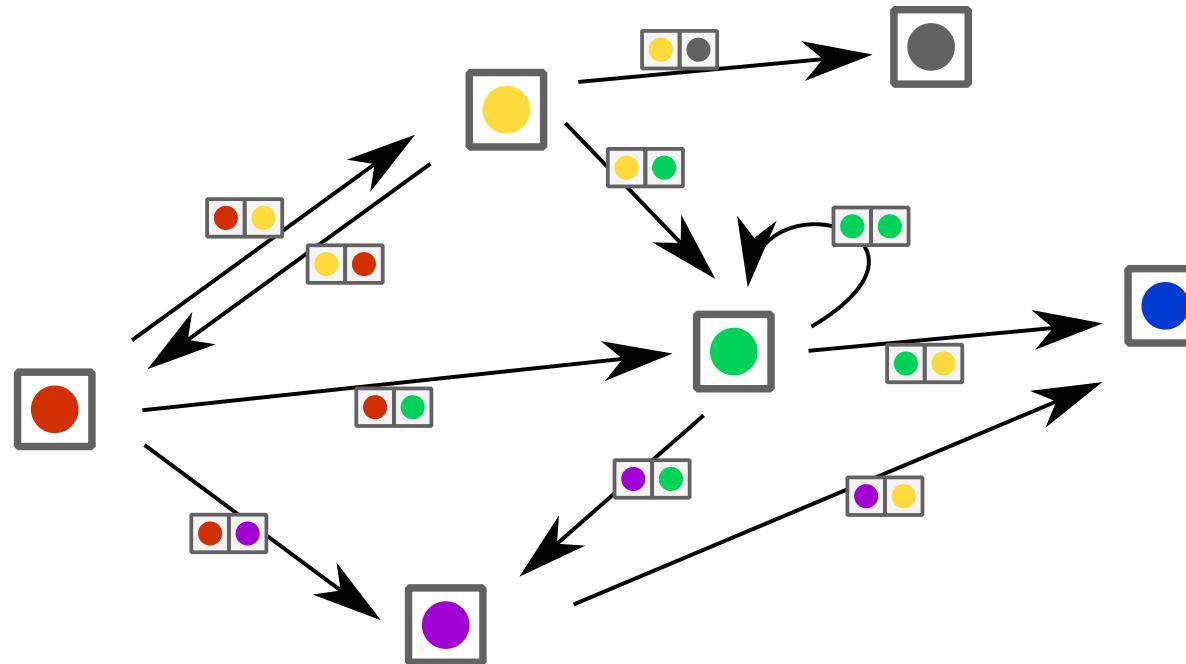


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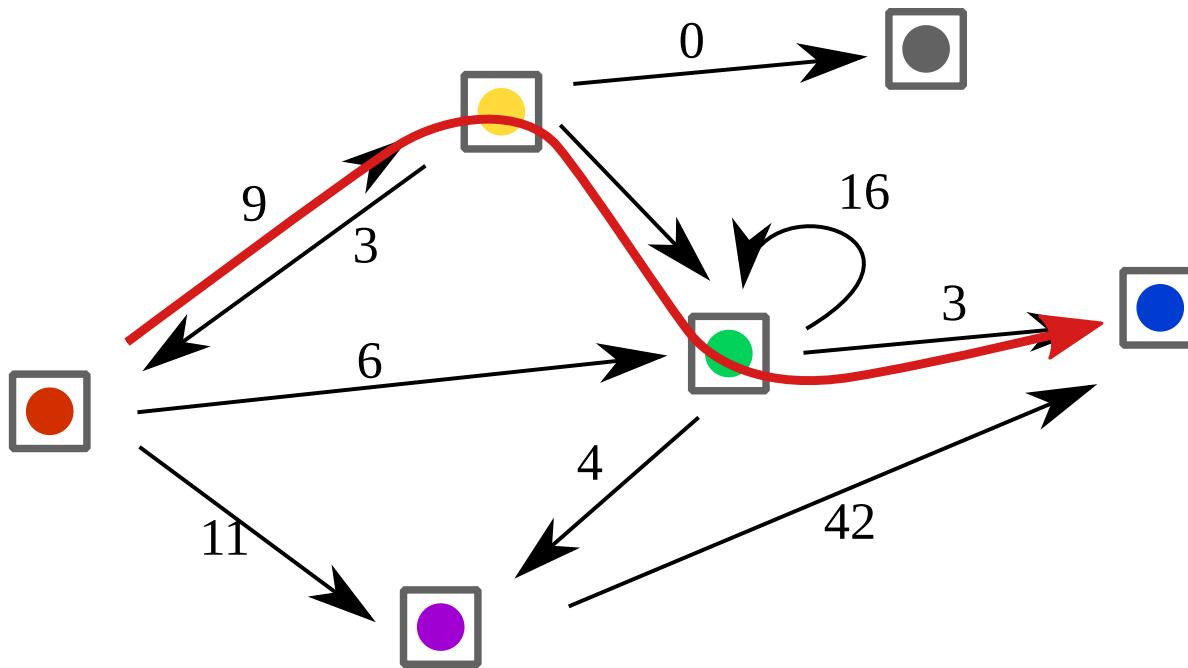
# Class of problems - Determine a Plan

Finding a *path* in a *graph* modeling all possible evolutions



# Class of problems - Plan Optimization

Finding an *optimized* path in a *weighted* Graph

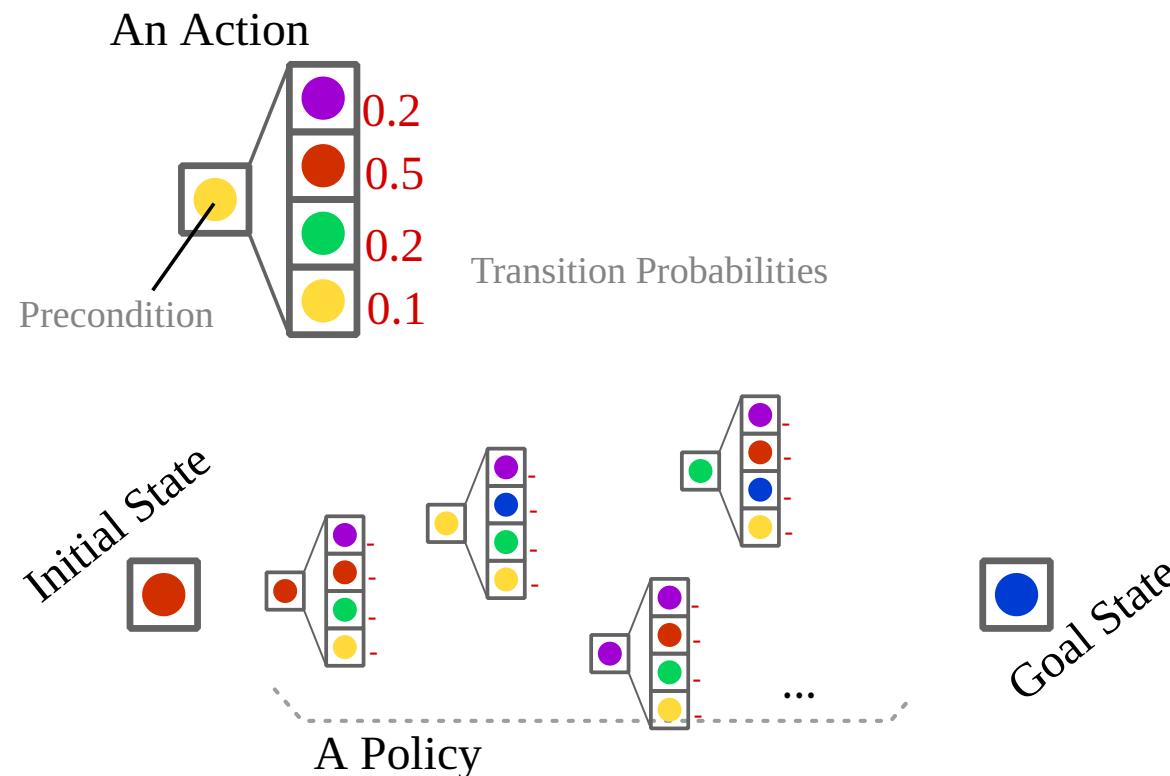


- ▶ Typically: *Finding the shortest path from A to B*

# Class of problems - Stochastic Planning

Build a *policy*:

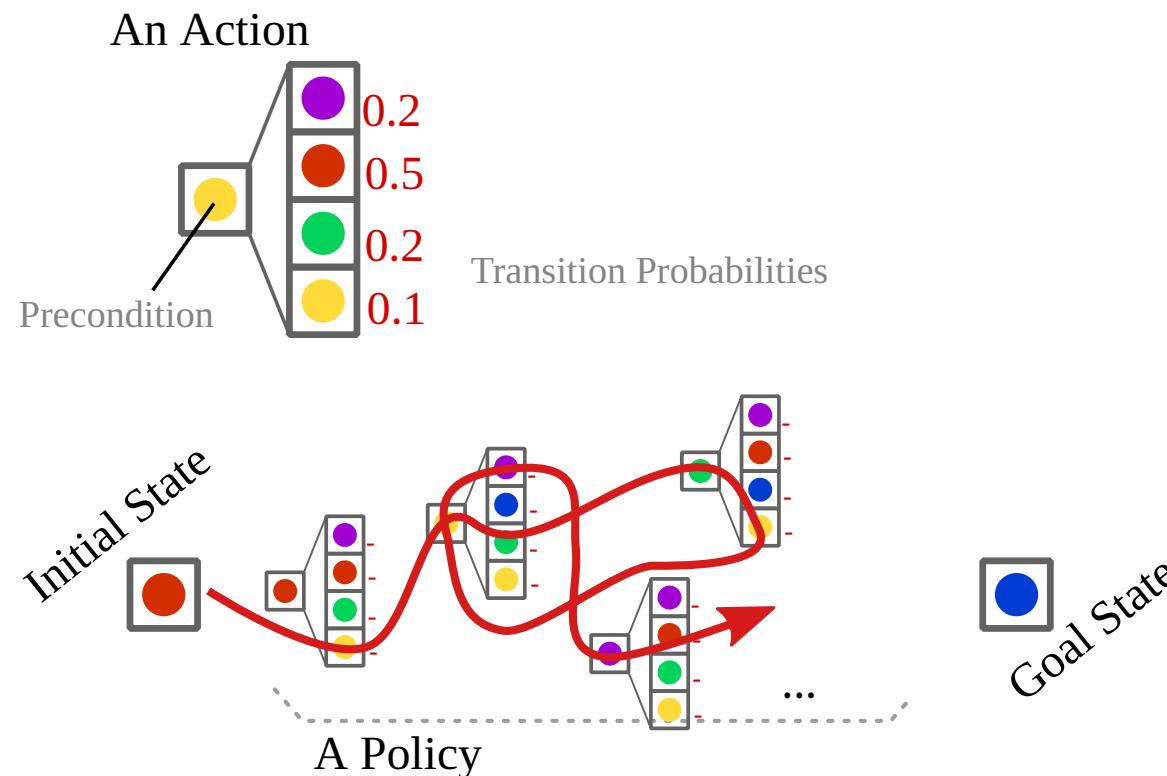
- ▶ Associate an *action* to perform *to each* reachable *state*



# Class of problems - Stochastic Planning

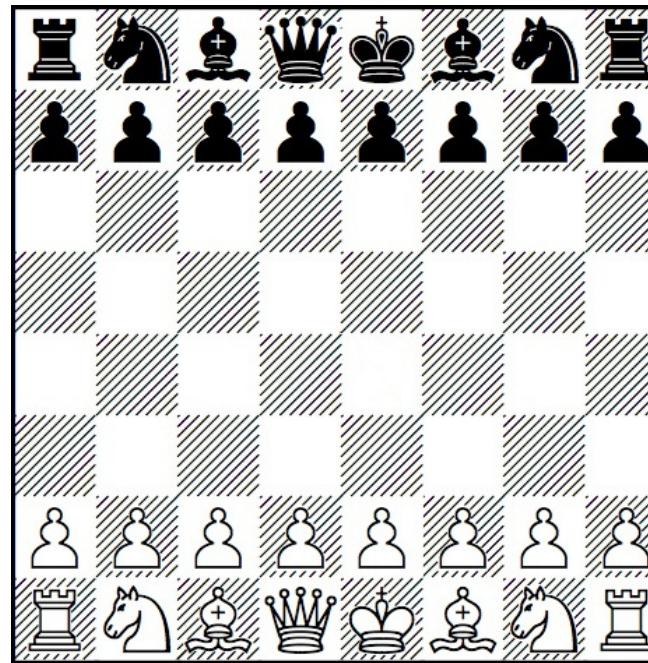
Execute a *policy*:

- ▶ Then, the effective succession of actions remains stochastic



# Class of problems - Game Theory

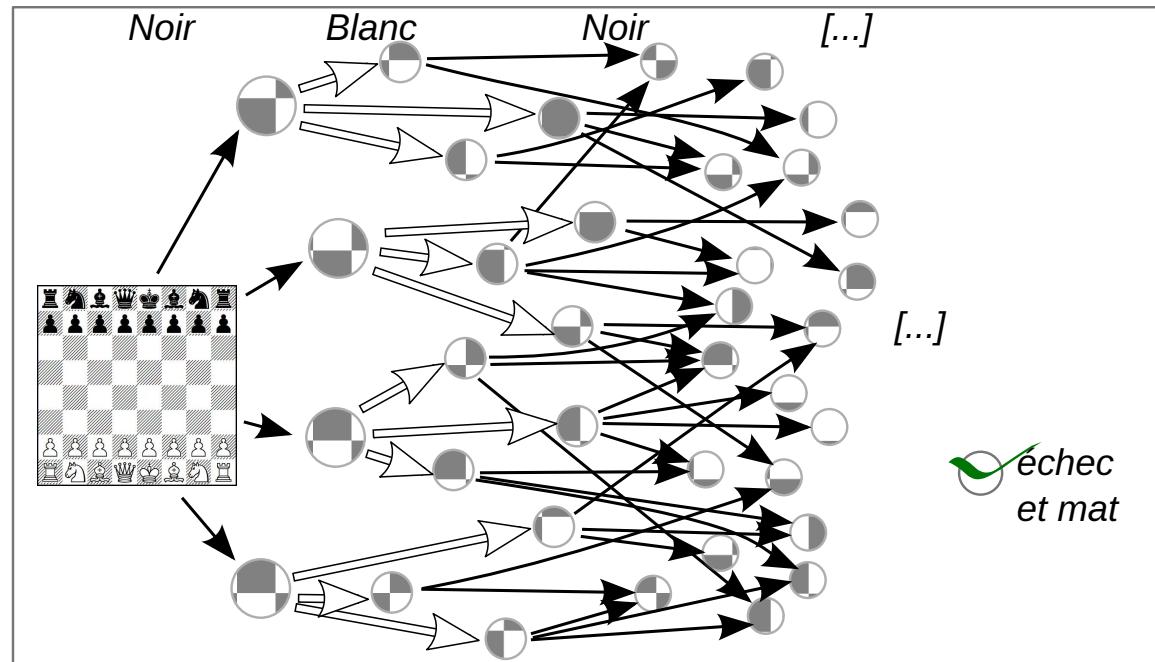
*Few entities* (players) control a system (with different goals)



- ▶ Which actions for each entity ?
- ▶ Which consequences ?

# Class of problems - Game theory

*Few entities* control the same system (with different goals)



- *Uncertainty*: At least on the actions of the other players.

# Class of problems - Game theory

Difficulty:

- ▶ The *size* of the system
  - The number of variables describing the system
- ▶ The branching possibilities
  - The number of both actions and outcomes possibilities
  - Stochastic interactions
- ▶ The observability
  - Typically the goals and actions or possibility of actions of the opponents
- ▶ The number of players

# Class of problems - Control Complex systems

## The Grail : Control Complex Systems

- ▶ A lot of entities in interactions



\_An entity:\_ an autonomous sub-system with its own goals and capabilities (an agent)

# Vocabulary

- ▶ **graph** composed of **node** and **edges**
- ▶ **State Automata** composed of **state** and **action**
- ▶ **planning**: finding a valid succession of **actions**
- ▶ **policy**: An **action** response to ever reachable situation (**state**)
- ▶ **determinist** versus **uncertain / stochastic**
- ▶ **system, control** (automation science)
- ▶ **Multi-Agent System, Decision Making (AI)**

# Notion of Agent

"I act therefore I am"

- ▶ my actions have an effect on the world
- ▶ **and** I have the choice to act or not

cf. "Bullshit Jobs" - David Graeber (2019)  
(p.132-133 fr. in version )

or the joy to be cause - Karl Groos (1901)

# **Notion of Agent - Simple definition**

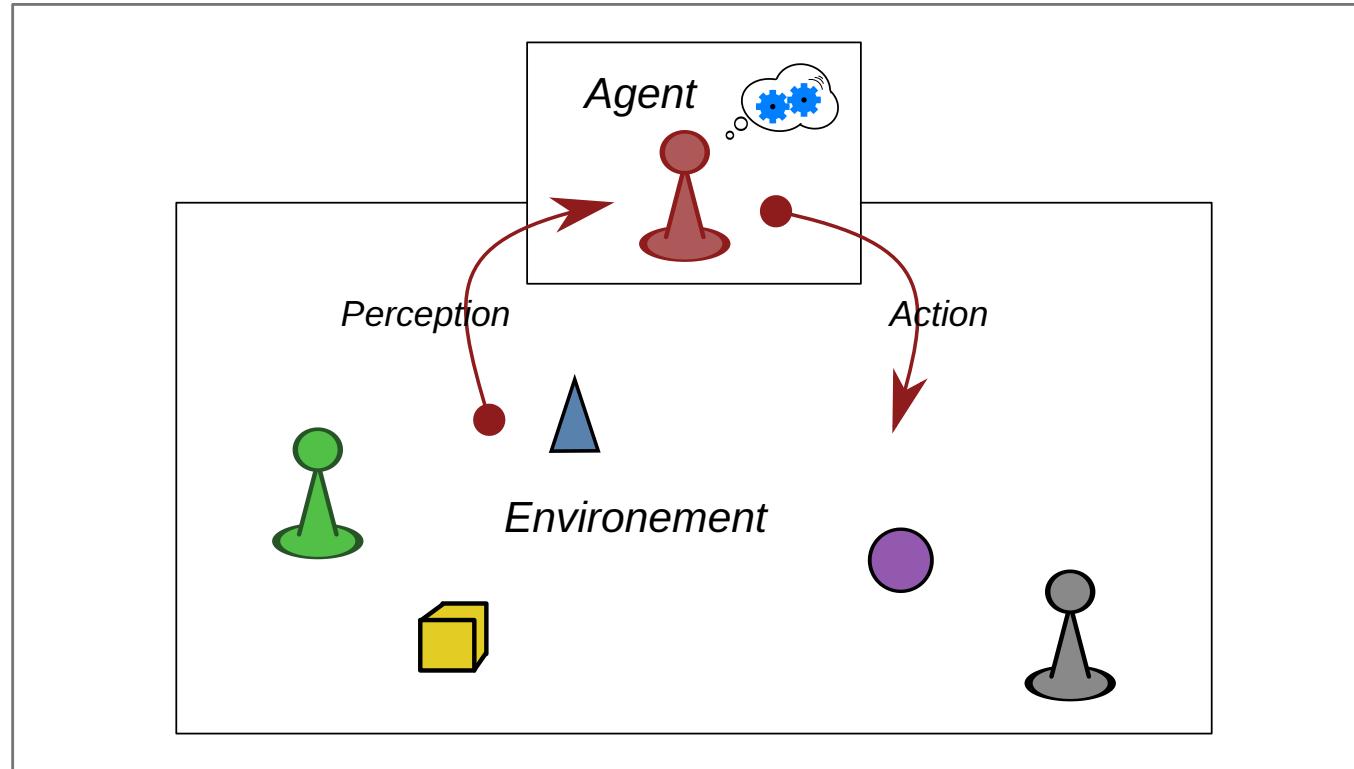
**An agent:**

**An entity capable of perception and action  
evolving in an environment.**

**Question:**

**How to choose appropriate action to perform  
considering the perception at each time step ?**

# Notion of Agent - Simple definition



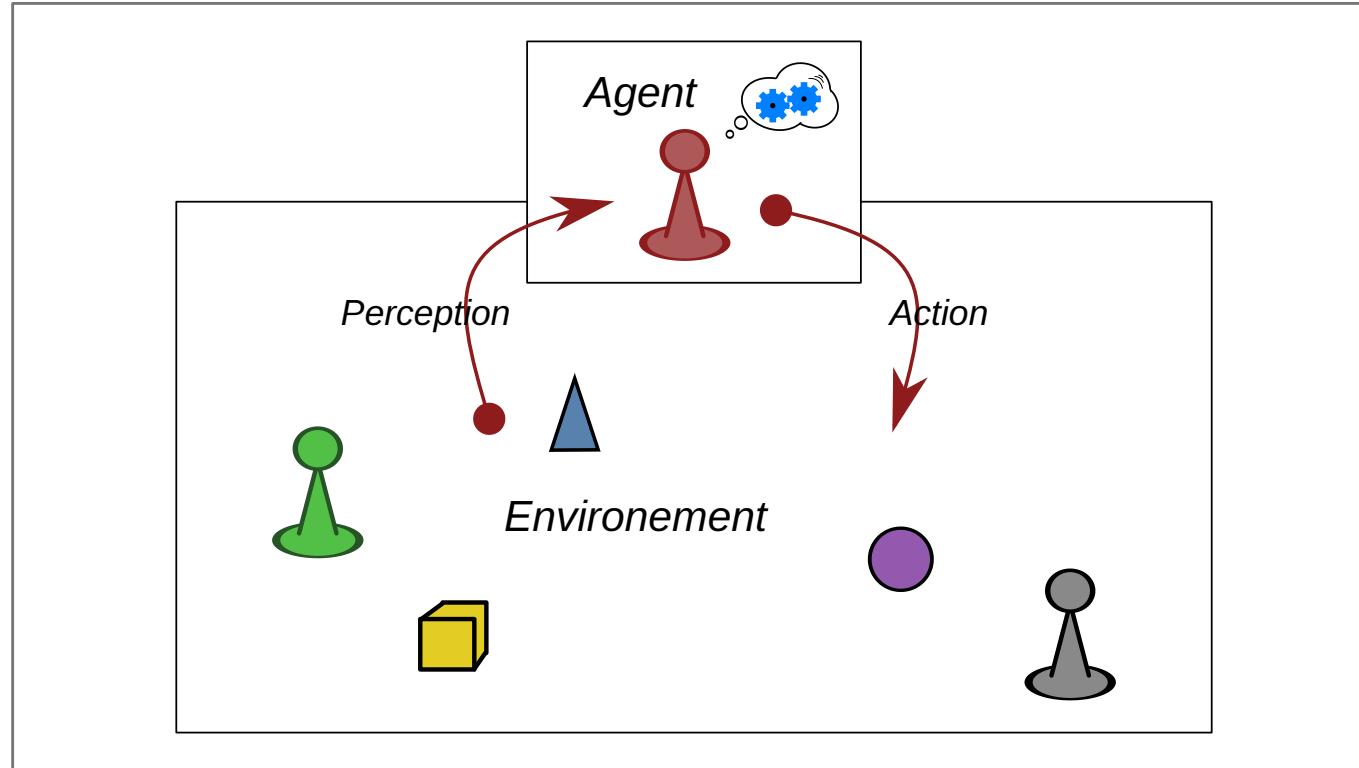
rarely determinist, mostly uncertain (even stochastic)

# Notion of Agent - Complementary Notions

## Agent:

- ▶ Defining by a perception-state, goals and a policy to achieve its goals  
(*BDI* model: Belief - Desire - Intention)
- ▶ with different positions in social structure  
(*AGR* model: Agent - Group - Role )
- ▶ Capable of communication
- ▶ Capable of adaptation (learning)
- ▶ Driven by emotions
- ▶ ...

# Notion of Agent - rational Agent



An Agent: is an entity

- ▶ capable of **perceiving** and **acting** in its environment
- ▶ and driven toward its **goals**

# Course notion to acquire

## Decision-making under uncertainty

- ▶ Policy as Script and Decision Tree
- ▶ Theoretical basis: **Markov Decision Process**
- ▶ The simplest algorithmic response: **Reinforcement Learning**
- ▶ **The curse of Dimensionality**
- ▶ Divide and Rule: **clustered** and **factored** model

## Game: 421

- ▶ Get the best combination
- ▶ by rolling 3 dices

### Goal :

- ▶ Optimize the 2 re-roll possibility
- ▶ by choosing dices to roll again.



## Game: 421

- 1. Understand the game
- 2. Implement your first AI
- 3. Think with Decision-Tree

Let's go....