

# Projet Int. Art. and Optimization

An introduction

Guillaume Lozenguez

[@imt-nord-europe.fr](mailto:@imt-nord-europe.fr)



**IMT Nord Europe**  
École Mines-Télécom  
IMT-Université de Lille

# 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



# Our topic: Autonomous Decision Making

- ▶ Model the capability of actions
- ▶ Learn action interest
- ▶ Model dynamic systems and plan
- ▶ Plan paths 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  $n = 10^{600}$ : around  $10^{583}$  years.  
 $\rightarrow$  requires decomposed model and statistics...

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

# Decision Making Problem

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

**Knowing that:**

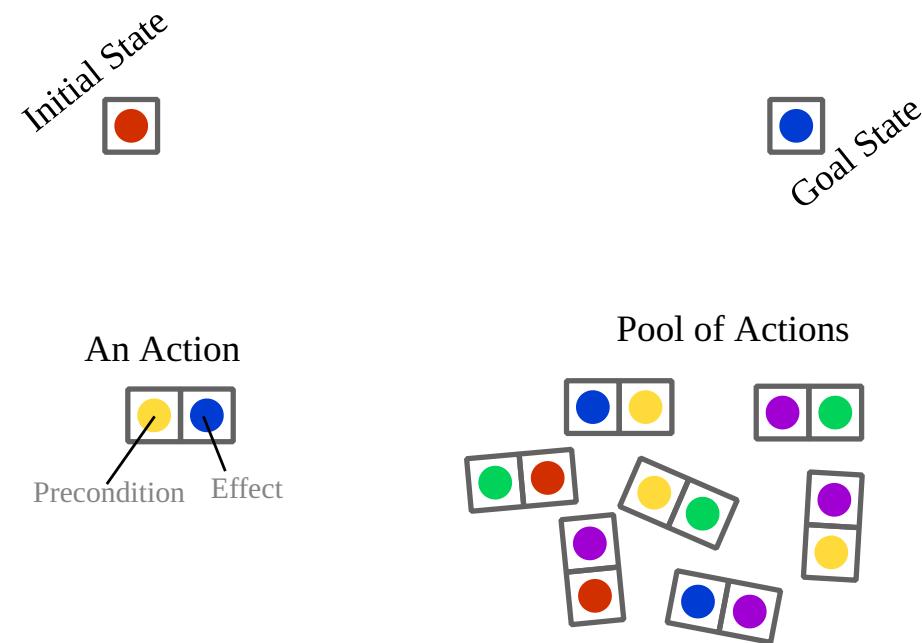
- ▶ Model could require very large exploration
- ▶ We potentially do not have the model
- ▶ Evolution is generally uncertain

# Introduction to Decision Under Uncertainty

1. Introduction
2. Class of problems (not class of complexity)
3. The notion of Agent
4. Decision Making Process

# Class of problems - Deterministic Planning

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

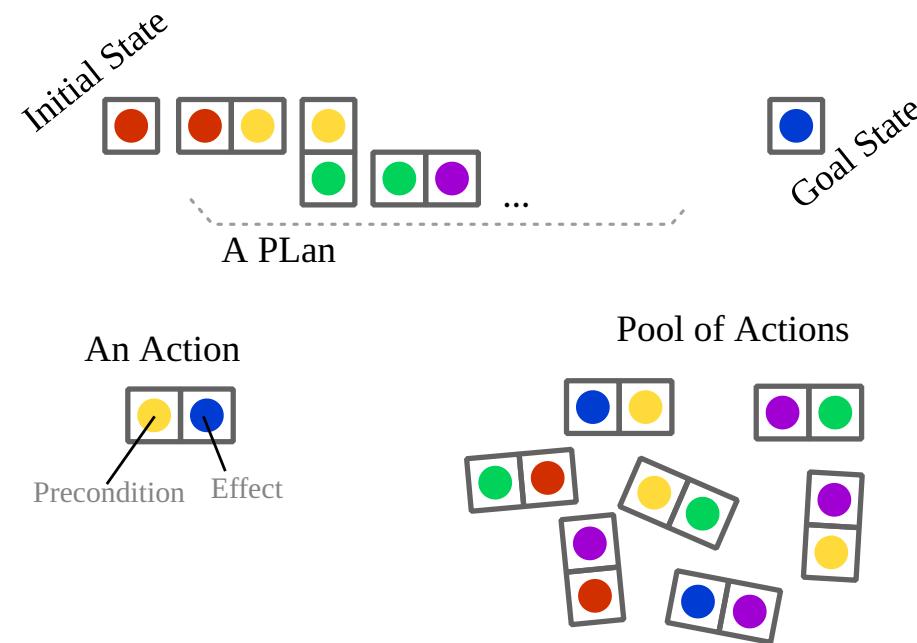


## Deterministic case:

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

# Class of problems - Deterministic Planning

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

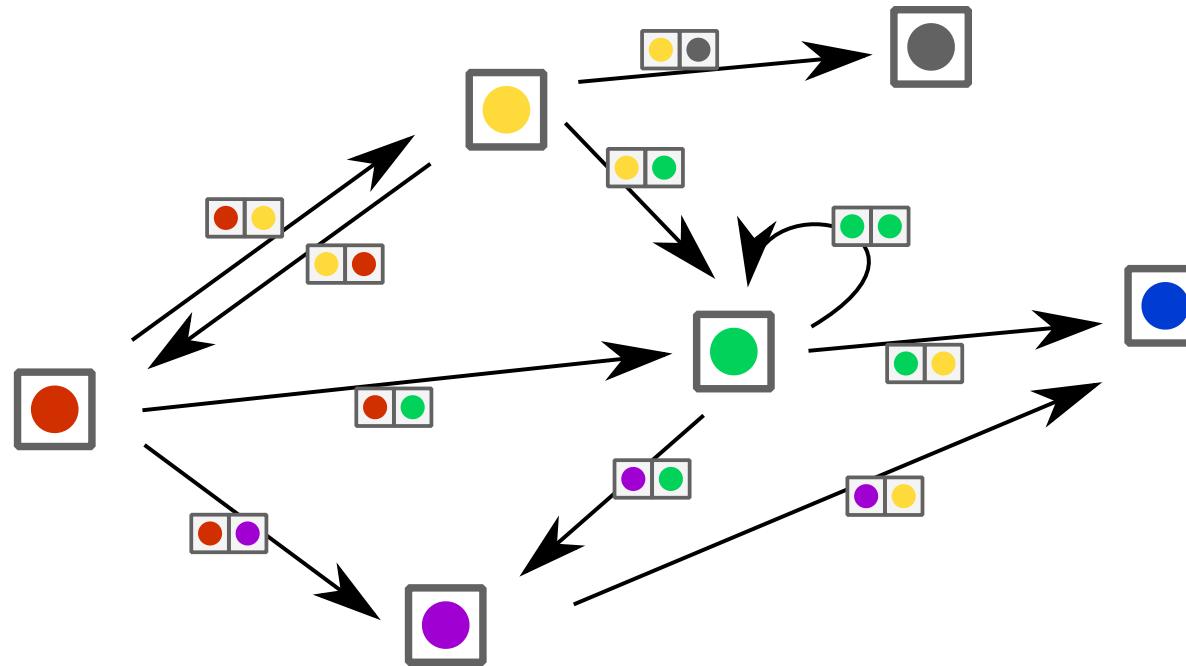


## Deterministic case:

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

# Class of problems - Determine a Plan

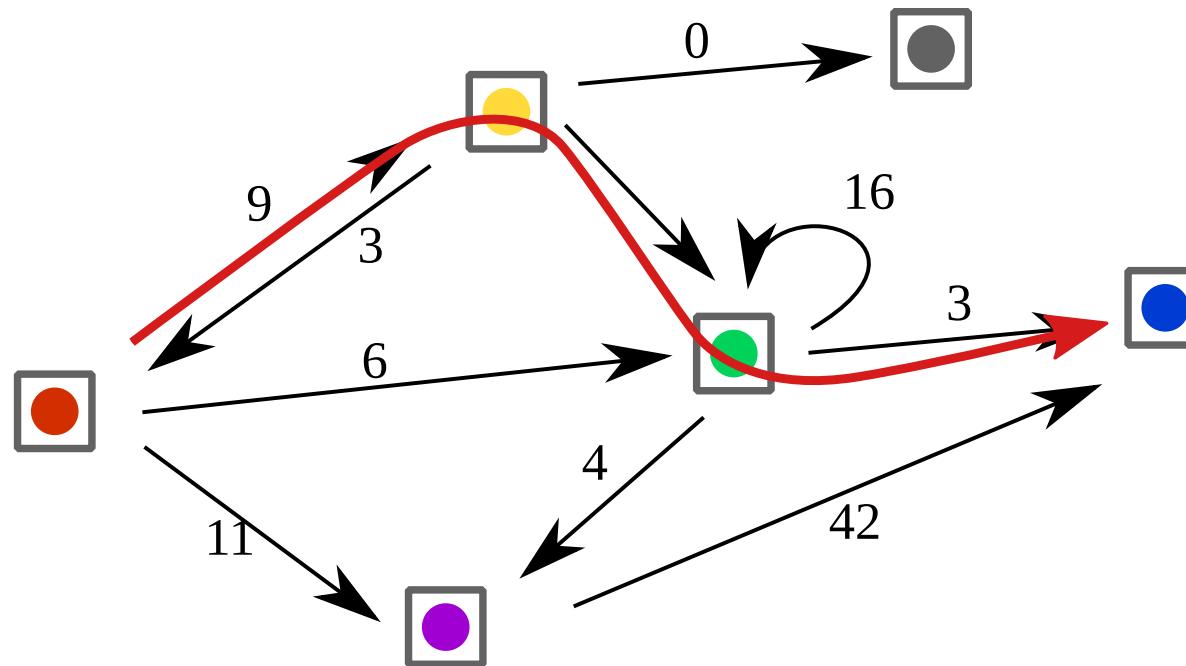
Finding a *path* in a *graph* modeling all possible evolutions



*Class of Complexity:* NP Hard (i.e. Non Polynomial over the number of nodes)

# Class of problems - Plan Optimization

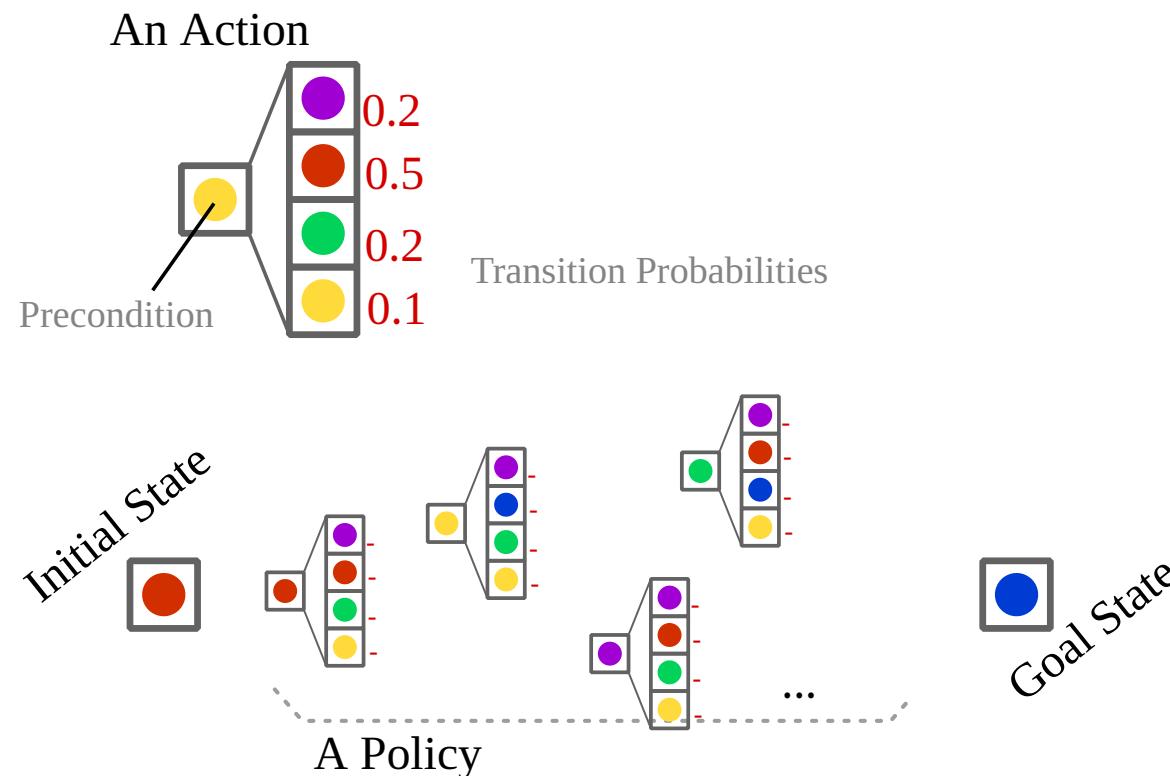
Finding an *optimized* path in a *weighted* Graph



# Class of problems - Stochastic Planning

Build a *policy*:

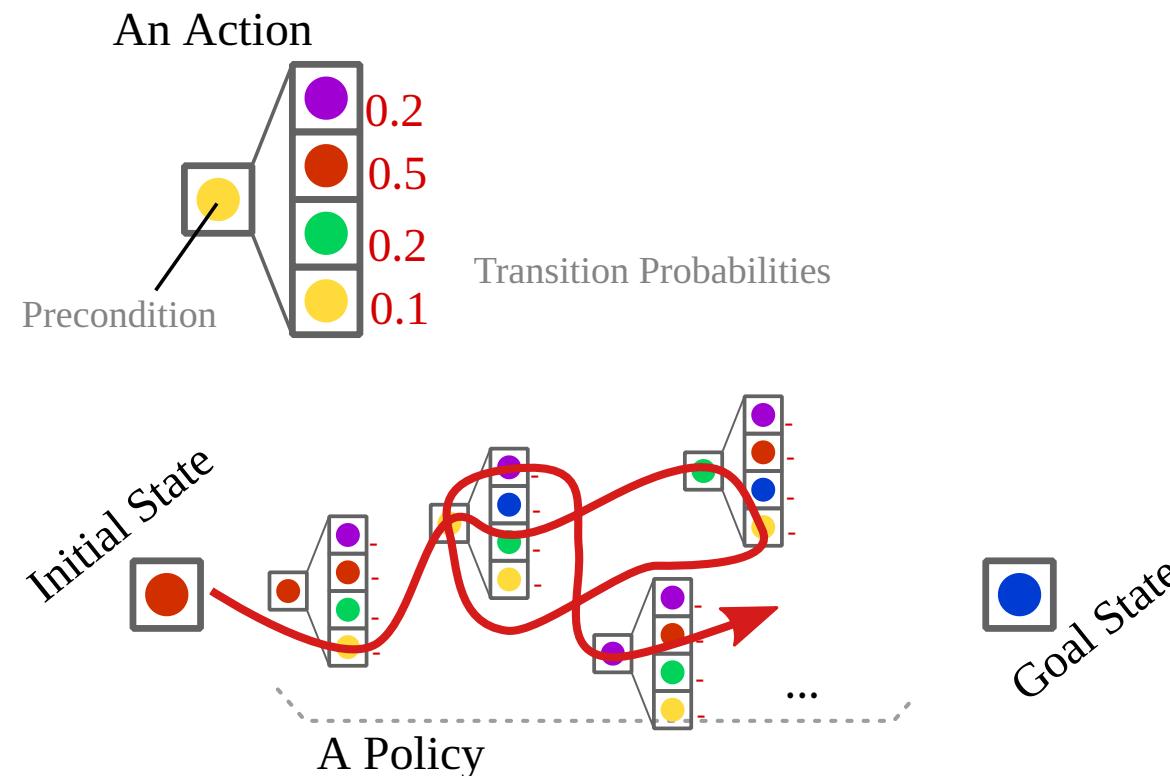
- ▶ Associate an *action* to perform *to each* reachable *state*



# Class of problems - Stochastic Planning

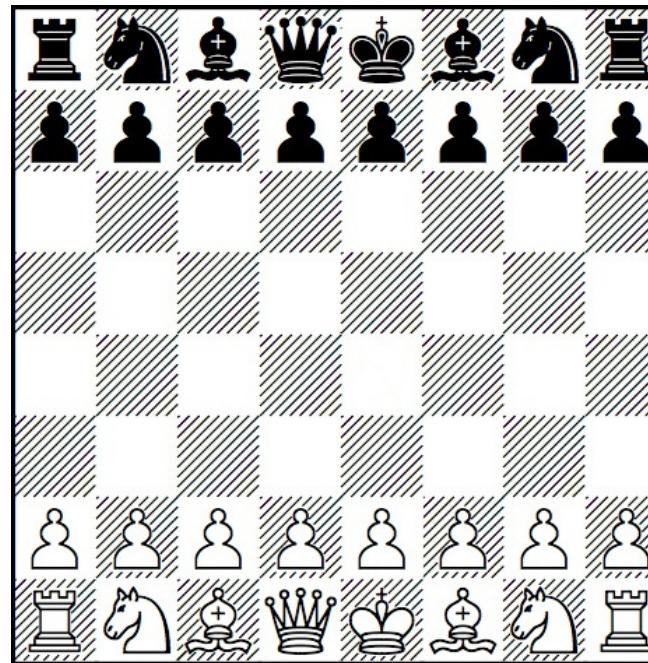
Execute a *policy*:

- ▶ Then, the effective succession of actions remains stochastic



# Class of problems - Game theory

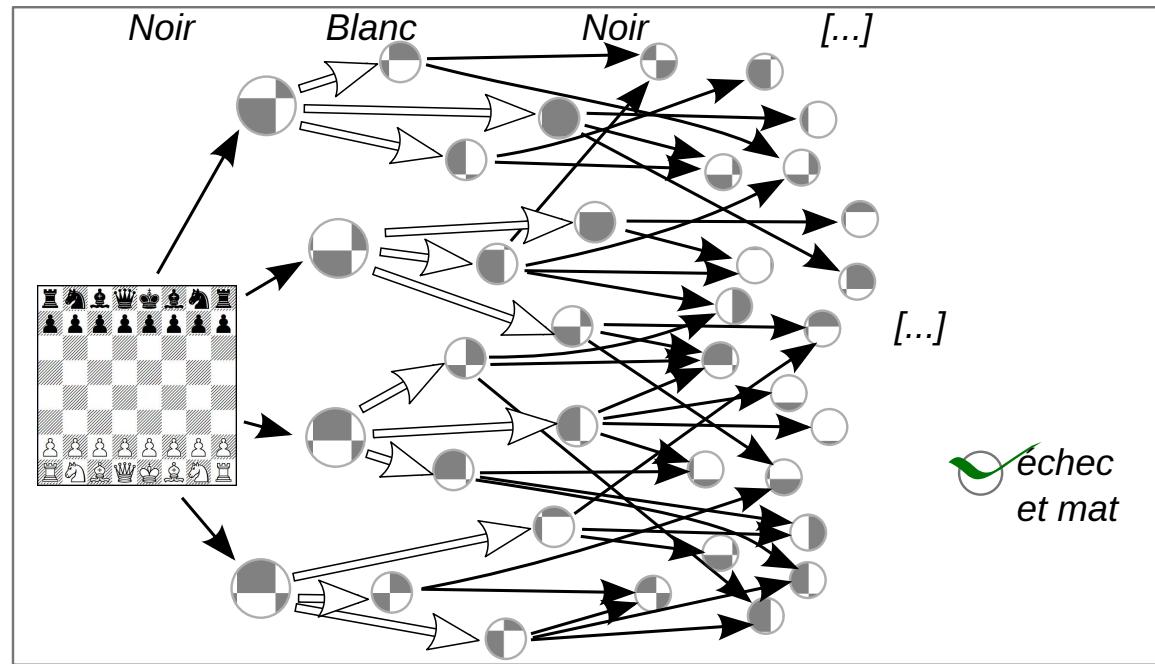
*Few entities* control the same system (with different goals)



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

# Class of problems - Game theory

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



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

# Class of problems - Control Complex systems

Complex systems:

- ▶ A lot of entities in interactions



- ▶ *Uncertainty*: ...

# Class of problems - Other components

- ▶ Sequential vs Simultaneous
- ▶ Finite or infinite horizon
- ▶ Multi-action per turn
- ▶ Complete observation
  - Informations are hidden
  - Different information over actors (players)
  - Require a memory
- ▶ Cooperative
- ▶ ...

# Vocabulary

- ▶ **graph** composed of **node** and **edges**
- ▶ **graph** composed of **state** and **action** (State Automata)
- ▶ **planning**: finding a valid succession of **actions**
- ▶ **determinist** versus **uncertain / stochastic**
- ▶ **system, control** (automation)
- ▶ **multi-agent system, decision-making** (AI)
- ▶ **observability**

# 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

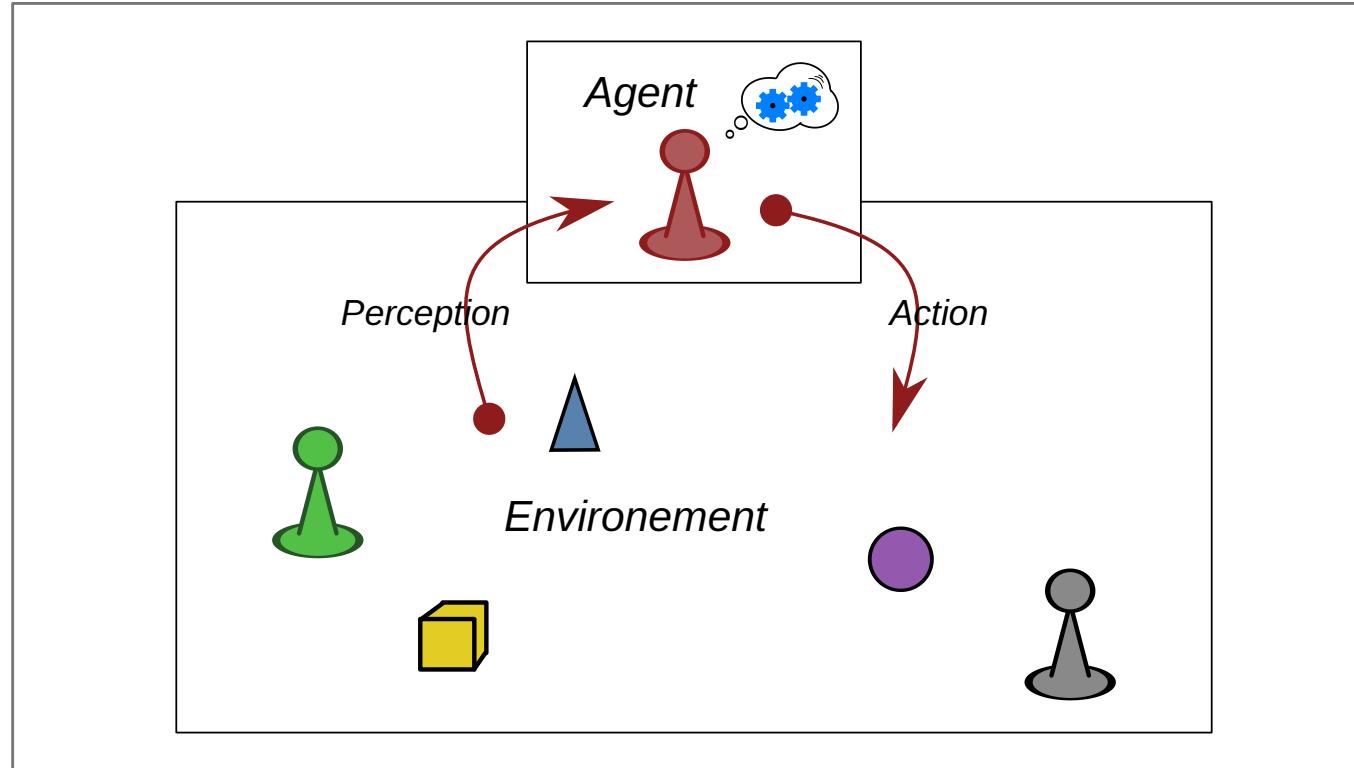
An agent:

**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
- ▶ ...

# Course notions

From *reactive control* to *deliberative control*

- ▶ Immediate response to stimuli

Script:

```
if .... do ...  
else if ... do ...
```

**versus**

- ▶ Model-based decision-making
  - with an opponent
  - and non-trivial optimization

# Course notions

## Decision-making under uncertainty (with me)

- ▶ Script, Policy and Decision Tree
- ▶ Reinforcement Learning:
  - Q-Learning (learn the policy)
  - Model-Learning (learn the model, compute the policy)
- ▶ Factored Model

## Game theory and adversarial technic

## Combinatorial Optimization technic

# Today Game: 421

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

## Goal :

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



**Let's go....**