

Decision Under Uncertainty

An introduction

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Our topic: Autonomous Decision Making

- ▶ Model the capability of actions
- ▶ Learn / Optimize policies of actions
- ▶ Handle large problem...

- ▶ **Quick Domain History**
- ▶ **Agent and Behavior**
- ▶ **Complexity**

Au commencement... - Les années 40

Alan Turing (1912 - 1954)

- ▶ **1936** - On Computable Numbers with an Application to the Entscheidungsproblem (14k citation)
 - *The Universal Machine* → *The Turing Machine*.
- ▶ **1950** - Computing Machinery and Intelligence
 - Le test de Turing (21k citation)

Computing Science and Artificial Intelligence are already close notions

Les années 60 - IA théorique et âge d'or de l'informatique

Richard E. Bellman (1920 - 1984)

- ▶ **1957** - A Markovian Decision Process
 - Mathématique appliquée

Edsger W. Dijkstra (1922 - 2002)

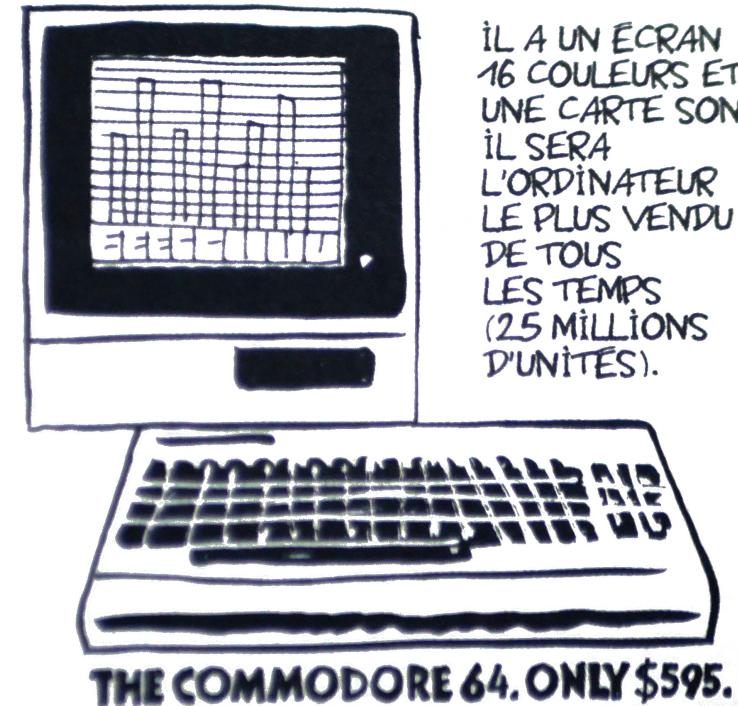
« La science informatique n'est pas plus la science des ordinateurs que l'astronomie n'est celle des télescopes »

- ▶ **1959** - A note on two problems in connexion with graphs
 - Algorithme de Dijkstra

Les années 80 - L'âge d'or de l'ordinateur

1982: Le Comodore 64

(La Revue Dessinée Vol.5)



IL A UN ÉCRAN
16 COULEURS ET
UNE CARTE SON.
IL SERA
L'ORDINATEUR
LE PLUS VENDU
DE TOUS
LES TEMPS
(25 MILLIONS
D'UNITÉS).

THE COMMODORE 64. ONLY \$595.

L'IA trouve un support pour exécuter ces théories.

L'IA moderne - sur le devant de la scène

Une triple conjoncture:

- ▶ Une théorie et des algorithmes matures
- ▶ Des clusters de calculs démocratisés
- ▶ Des données brutes à profusion

| L'avènement du Deep-Learning.

L'IA moderne - quelques dates

- ▶ **1998** - LeNet - un réseau neuronal convolutif (1989-1998)
 - "Gradient-based learning applied to document recognition"
Y. LeCun, L. Bottou, Y. Bengio et P. Haffner
- ▶ **Nov. 2007**, Carnegie-Mellon win the Darpa Urban Challenge (2M\$)



- ▶ **Oct. 2015** - First release of Tesla Autopilot

L'IA moderne - quelques dates (suite)

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



- ▶ **2017** - "Attention is all you need"

*A. Vaswani, N. Shazeer, N. Parmar, J. Uszkoreit, L. Jones,
A.N. Gomez, Ł. Kaiser, I. Polosukhin* (92k citations)

— Solution pour l'IA générative.

- ▶ **nov. 2022**, Lancement de ChatGPT

My Research Topic - Distributed Decision Making

Distributed Artificial Intelligence

- ▶ **Intelligence** - Simpelly referencing natural intelligence
- ▶ **Artificial** - But not natural (based on computing technic)

AI: The models and algorithms coping natural intelligence

- ▶ **Distributed** - In opposition to centralized - spread on distinct systems

Decision Making Under Uncertainty

- ▶ **Planning** - infers consequences of choices (retro-action)
- ▶ **Coordination** - and do it with multiple entities

- ▶ Quick Domain History
- ▶ **Agent and Behavior**
- ▶ Complexity

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 - Not reserved to Artificial Intelligence

"I act therefore I am"

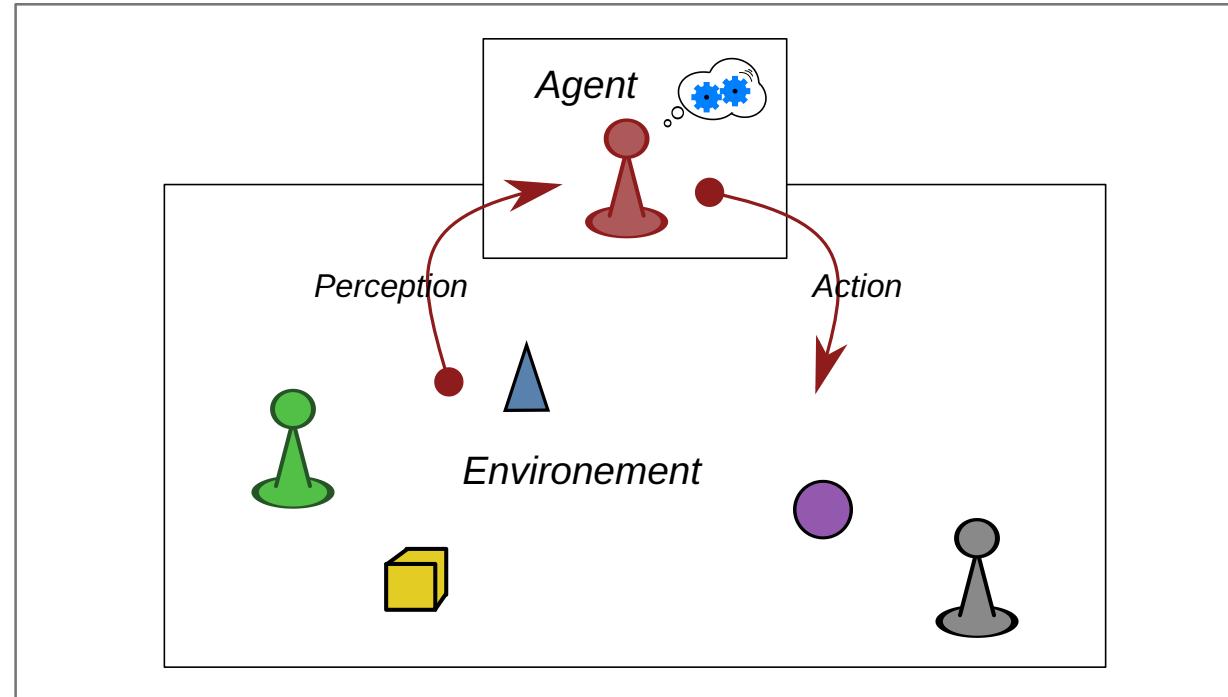
- ▶ my actions have an effect on the world
- ▶ **and** I have the choice to act or not

cf. "*Bullshit Jobs*" - David Graeber (2019)

(p.132-133 fr. in version)

or "*The joy to be cause*" - Karl Groos (1901)

Perception/Action Loop - notion of Retro-Action



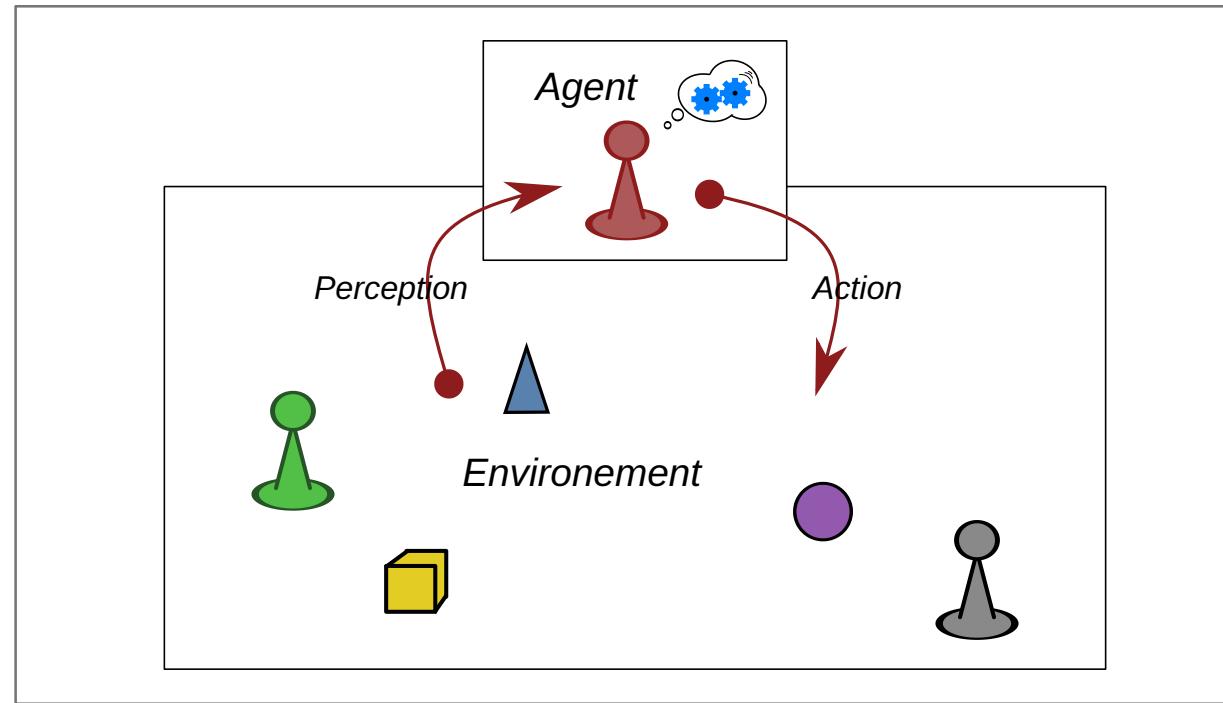
Rarely determinist, mostly uncertain (even stochastic)

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
- ▶ ...

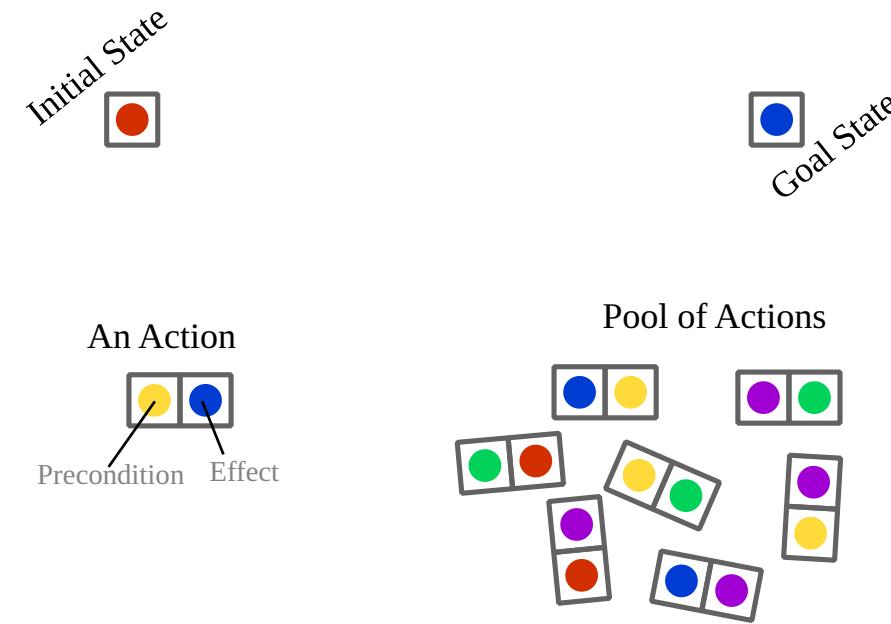
Rational Agent



- ▶ Capable of **perception** and **action**
- ▶ Driven toward its **goals** (**Desire** in **BDI** model)
(*I.E.* Somehow, a value function allows to optimise the course of actions)

Deterministic Planning

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

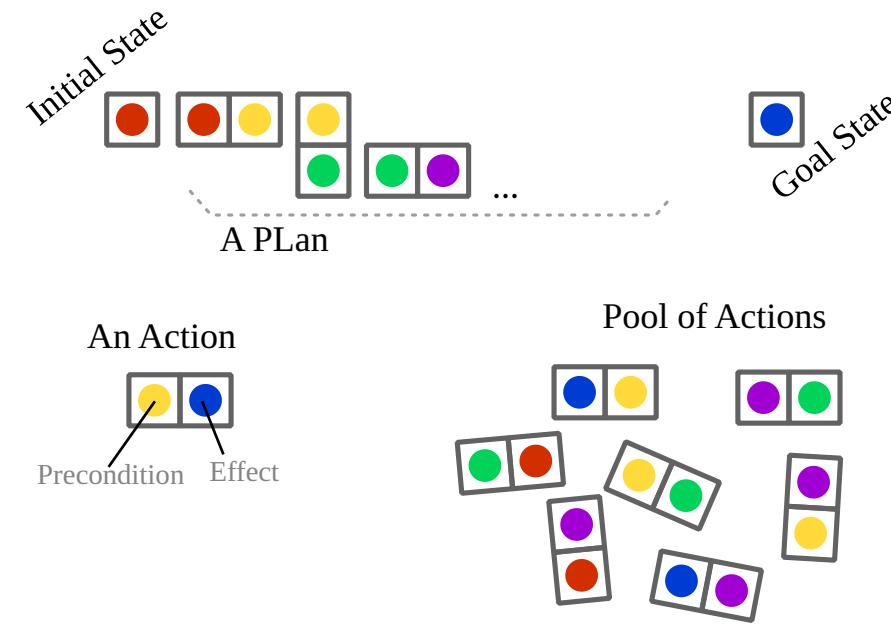


Deterministic case:

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

Deterministic Planning

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

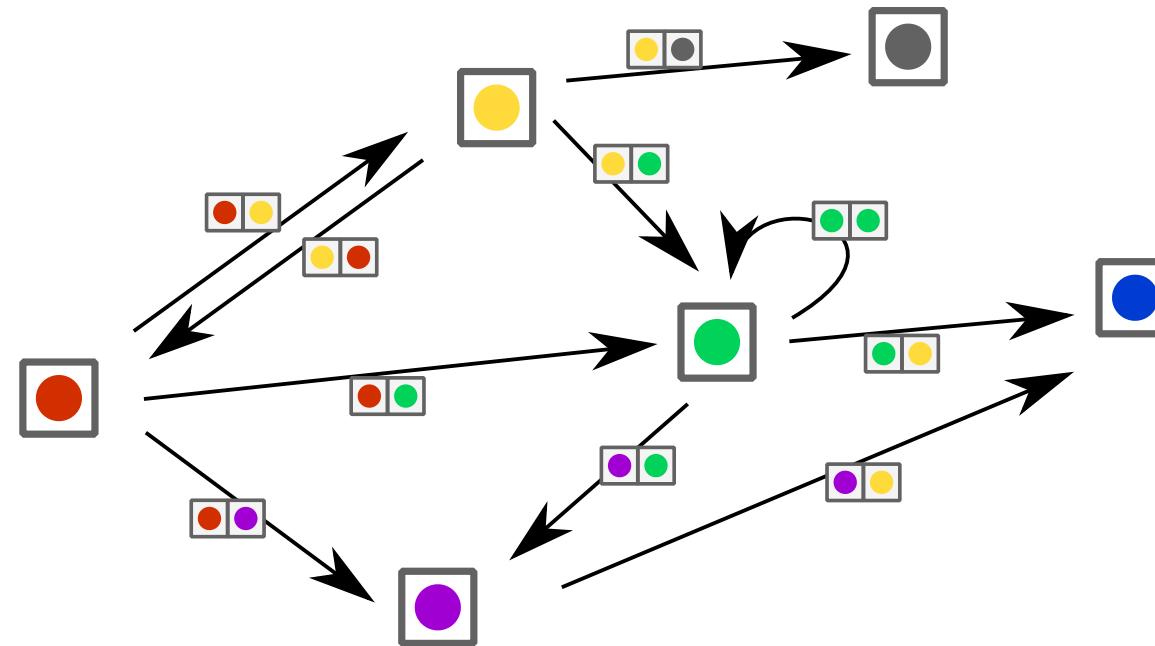


Deterministic case:

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

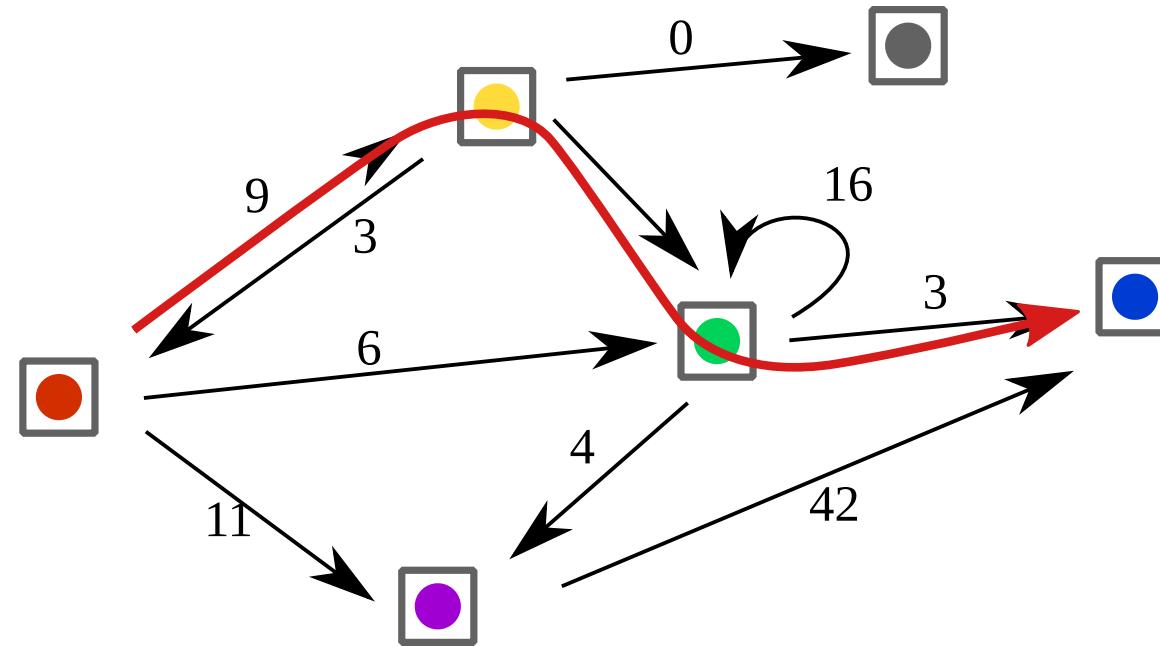
Determine a Plan

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



Plan Optimization

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

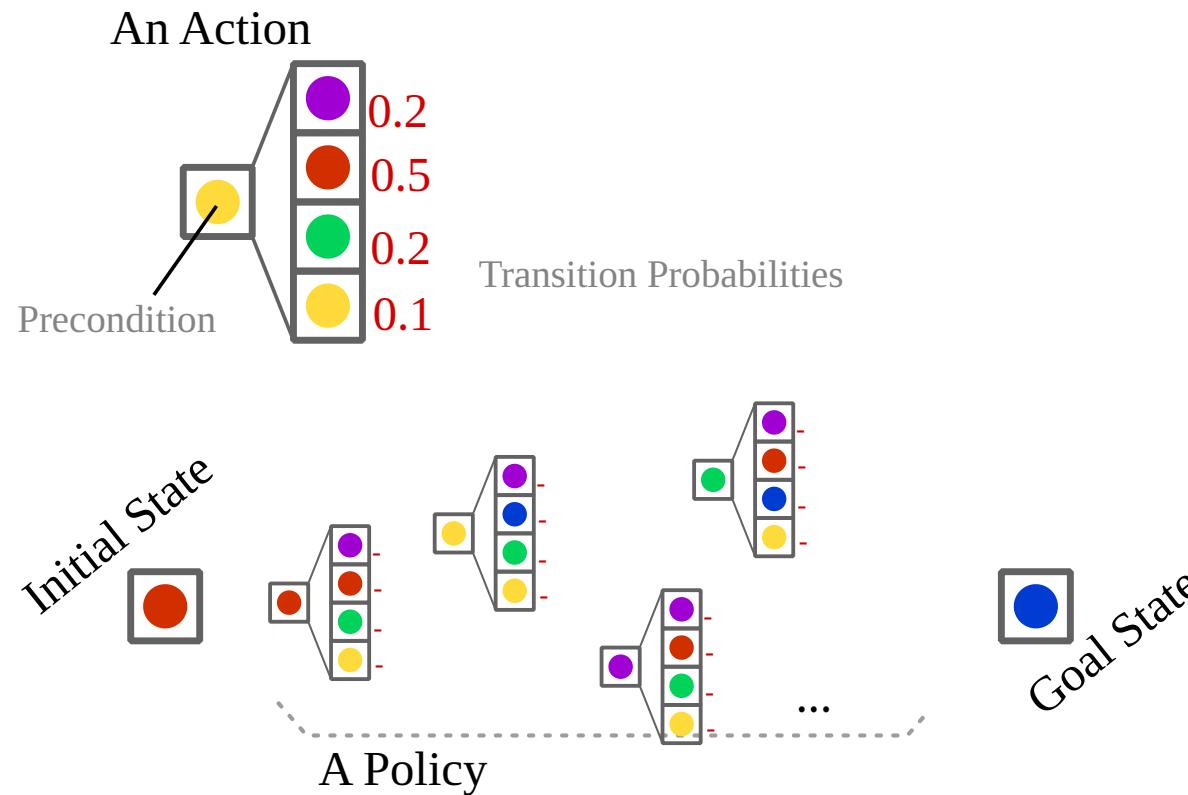


- ▶ Typically: *Finding the shortest path from A to B*

Stochastic Planning

Build a *policy*:

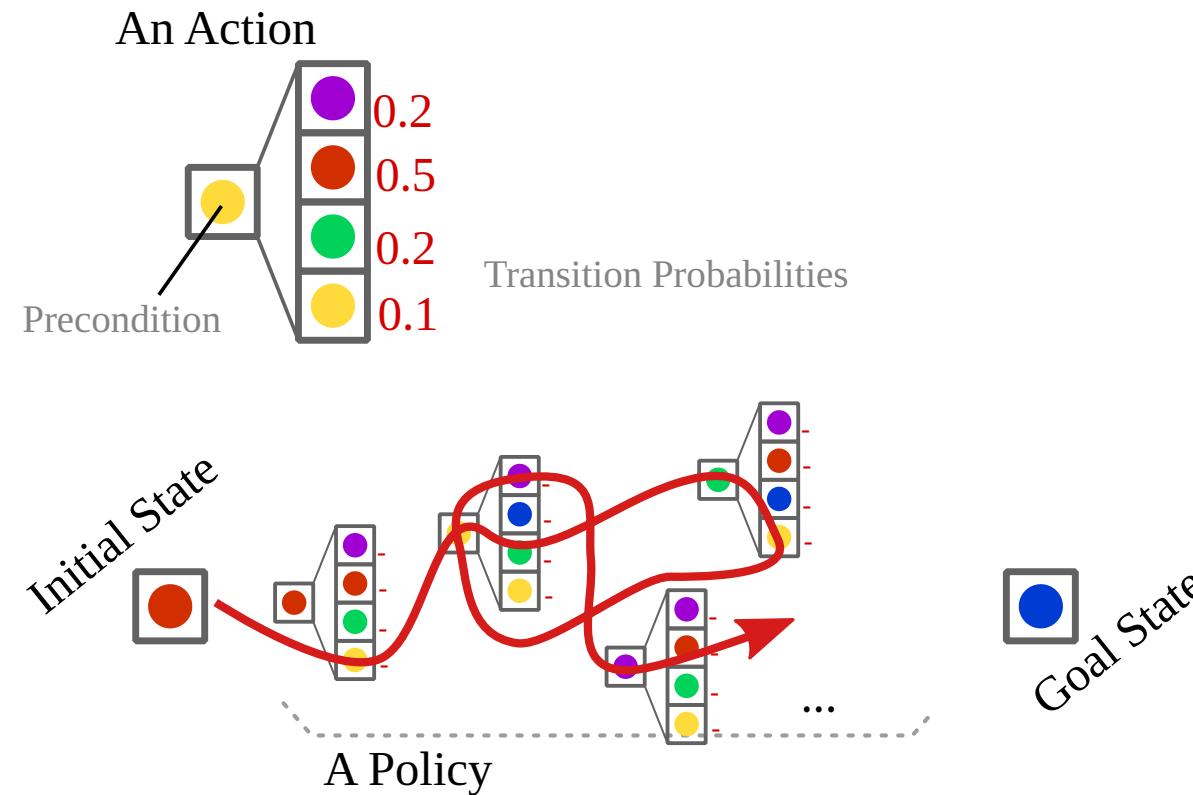
- ▶ Associate an *action* to perform *to each* reachable *state*



Stochastic Planning

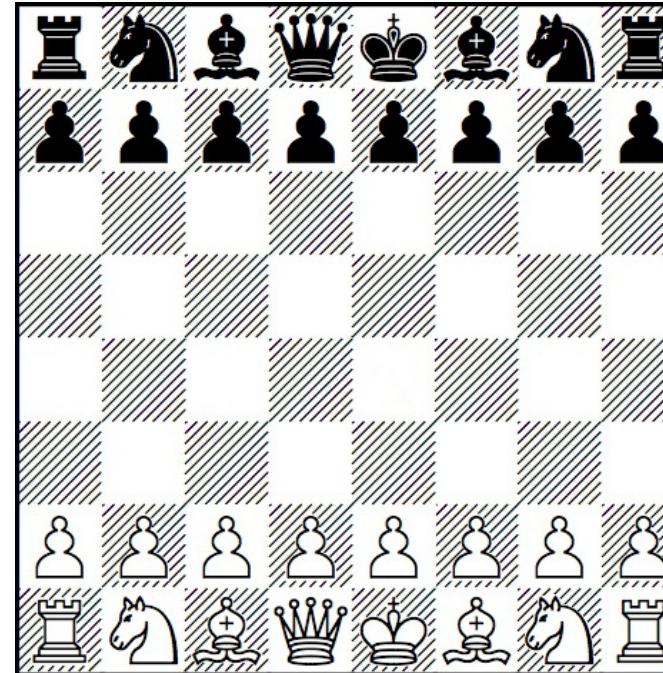
Execute a *policy*:

- ▶ Then, the effective succession of actions remains stochastic



Game Theory

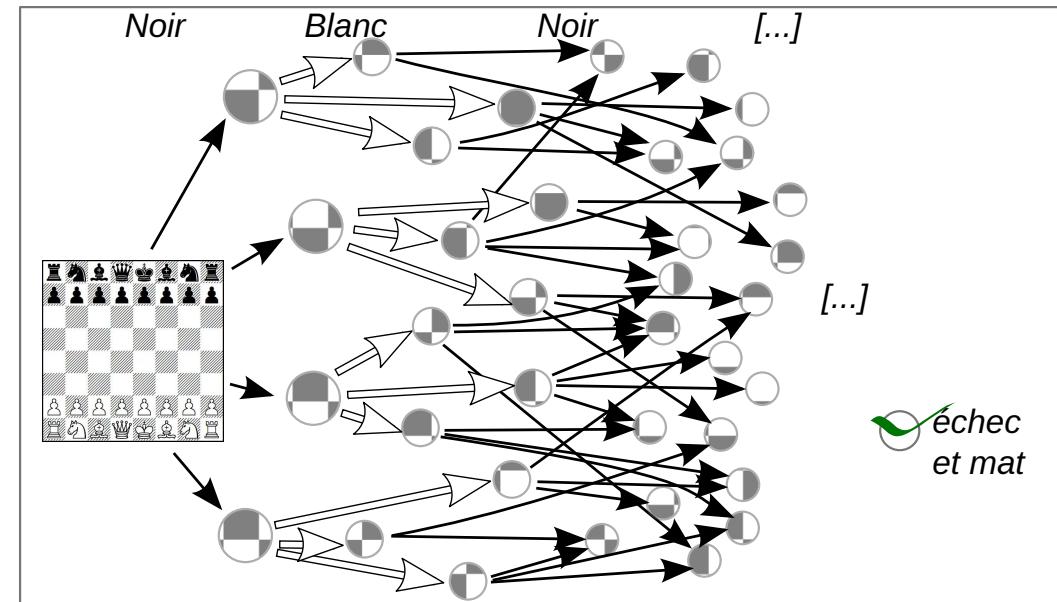
Few entities (players) control a system (with different goals)



- ▶ 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.

- ▶ Quick Domain History
- ▶ Agent and Behavior
- ▶ **Complexity**

Evaluate a complexity

- ▶ **Number of States** or configurations
Number of possible snapshot of a system
- ▶ **Number of Actions** - Number of control possibilities
- ▶ **Branching** - Number of reachable states from a given configuration
- ▶ **Horizon** - Number of time steps before feedback

The notion of complexity (example of Go)

GO: 19×19 positions $\rightarrow 10^{170}$ configurations $\rightarrow 10^{600}$ games



For comparison: 10^{120} possible games in chess

Professional AI: 2015

The notion of complexity (example of Go)

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

Enumerating all games: $O(n)$ with $n = 10^{600}$: 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:

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

Game: 421

**Reaching the best combination
by rolling 3 dices**

Goal :

- ▶ Optimize the 2 re-roll possibility
- ▶ By choosing dices to roll again.
- ▶ The best ever is **4 – 2 – 1**



Game 421 - The Quiz...

► Number of States ?

Game 421 - The Quiz...

► **Number of States** ? As a cartesian product of state variables:

- variable: *Die-1* ; domain: *1-6*
- variable: *Die-2* ; domain: *1-6*
- variable: *Die-3* ; domain: *1-6*
- variable: *Counter* ; domain: *1-3*

$$6 \times 6 \times 6 \times 3 = 648$$

Game 421 - The Quiz...

- ▶ **Number of States ?** In facts, the order do not mater.

(Mathematiques area: [Combinatorics](#))

Get 3 elements in 1-6 : $56 \times \text{counter} = 168$

Game 421 - The Quiz...

► Number of Action ?

Game 421 - The Quiz...

► Number of Action ?

- variable: *Act-1* ; domain: *Keep-Roll*
- variable: *Act-2* ; domain: *Keep-Roll*
- variable: *Act-3* ; domain: *Keep-Roll*

$$2 \times 2 \times 2 = 2^3 = 8$$

Game 421 - The Quiz...

► Branching ?

Game 421 - The Quiz...

► Branching ?

Worst case: with action "*roll-roll-roll*" → **56** possibilities

► Horizon ? **3**

► Games ? $56 \times 56 \times 56 = \textcolor{blue}{175\,616}$

Game 421 - Implementation:

<https://imt-mobisyst.bitbucket.io/hackagames>

Web dev. environment: <https://replit.com>