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

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Au commencement... - Les années 40

Alan Turing (1912 - 1954)

- **1936 -** On Computable Numbers with an Application to the Entscheidungsproblem (14k citation)
  - *The Universal Machine* $\rightarrow$ *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 appliqué

Edsger W. Dijkstra (1922 - 2002)

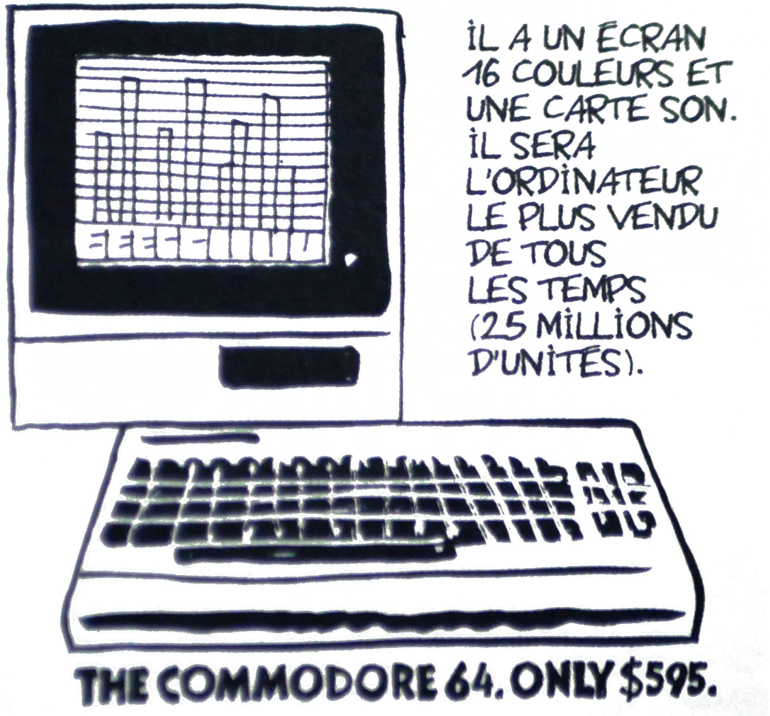
« La science informatique n’est pas plus la science des ordinateurs que l’astronomie n’est celle des télescopes »

- **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)



> 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
- **Artifical** - 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

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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 a each time step ?

Notion of Agent - Not reserved to Artificial Intelligence

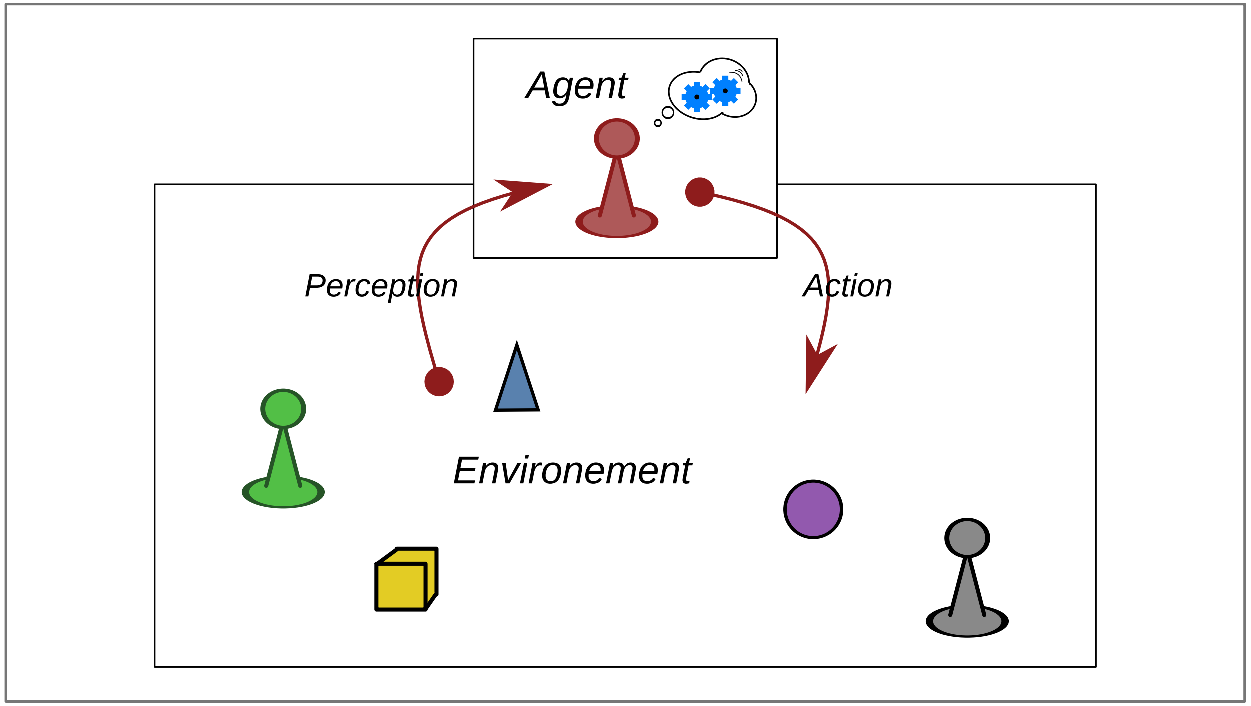
"I act therefore I am"

- 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



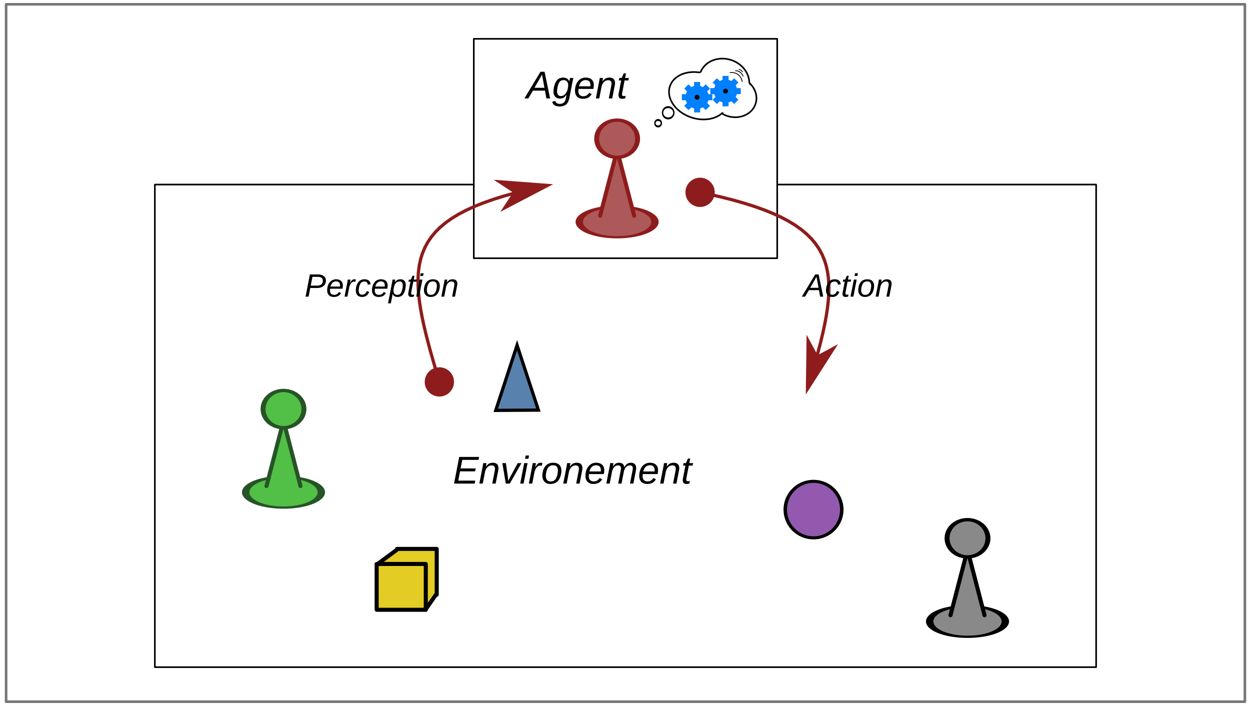
Rarely determinist, mostly uncertain (even stochastic)

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

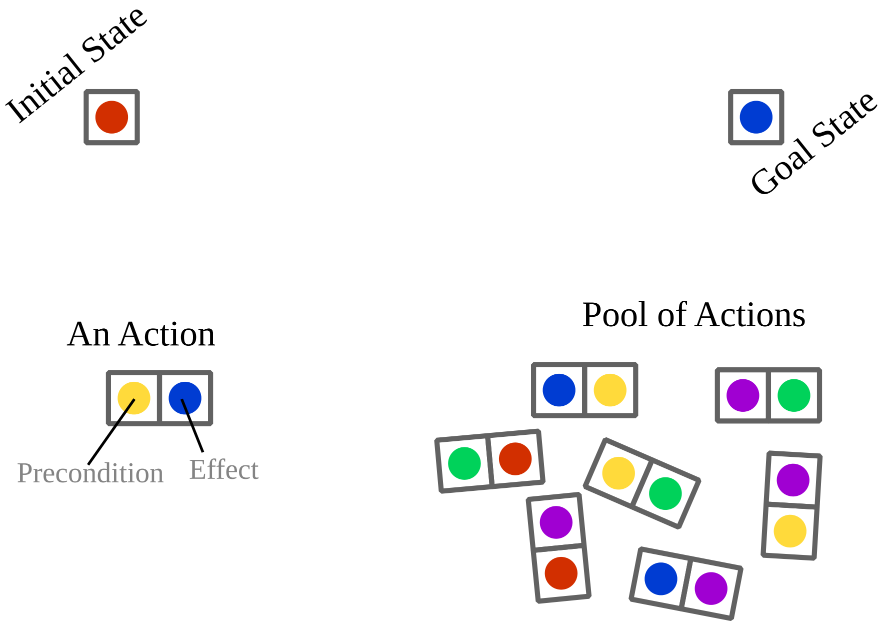


- Capable of **perception** and **action**
- Driven toward its **goals** (**Desire** in **BDI** model)

(*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.

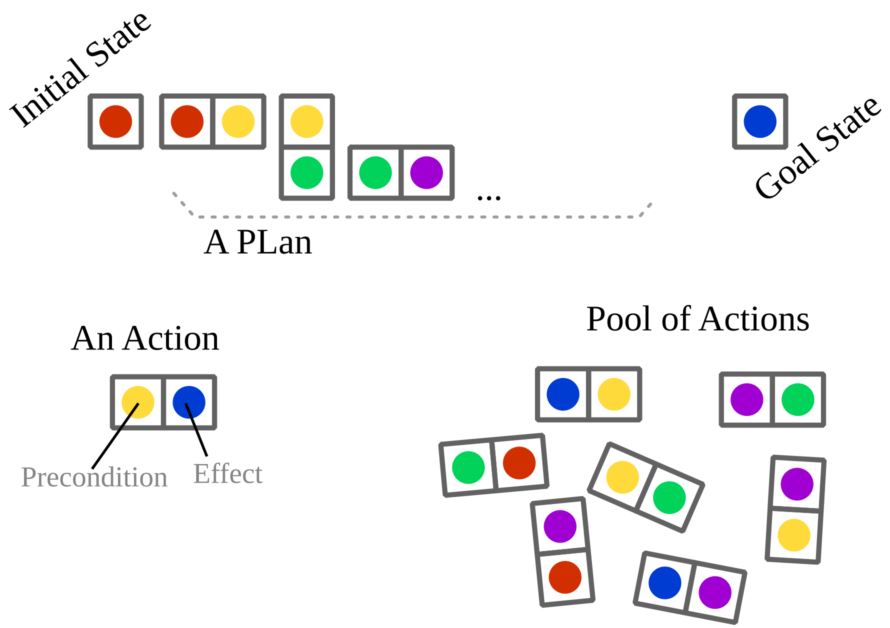


Deterministic case:

- 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.

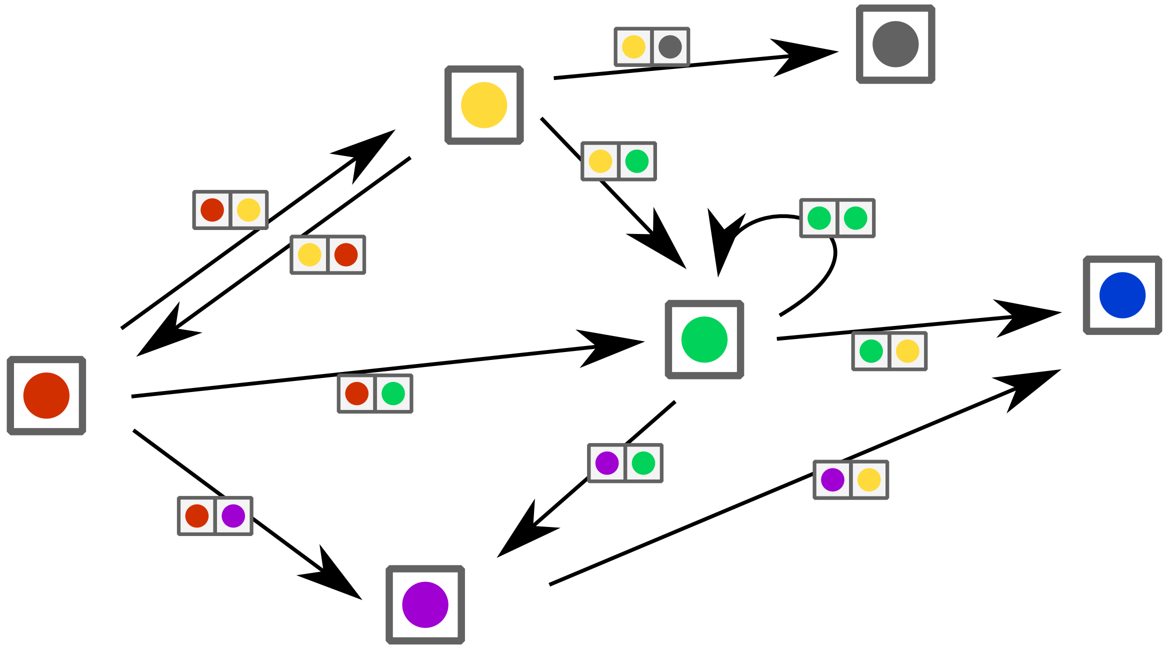


Deterministic case:

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

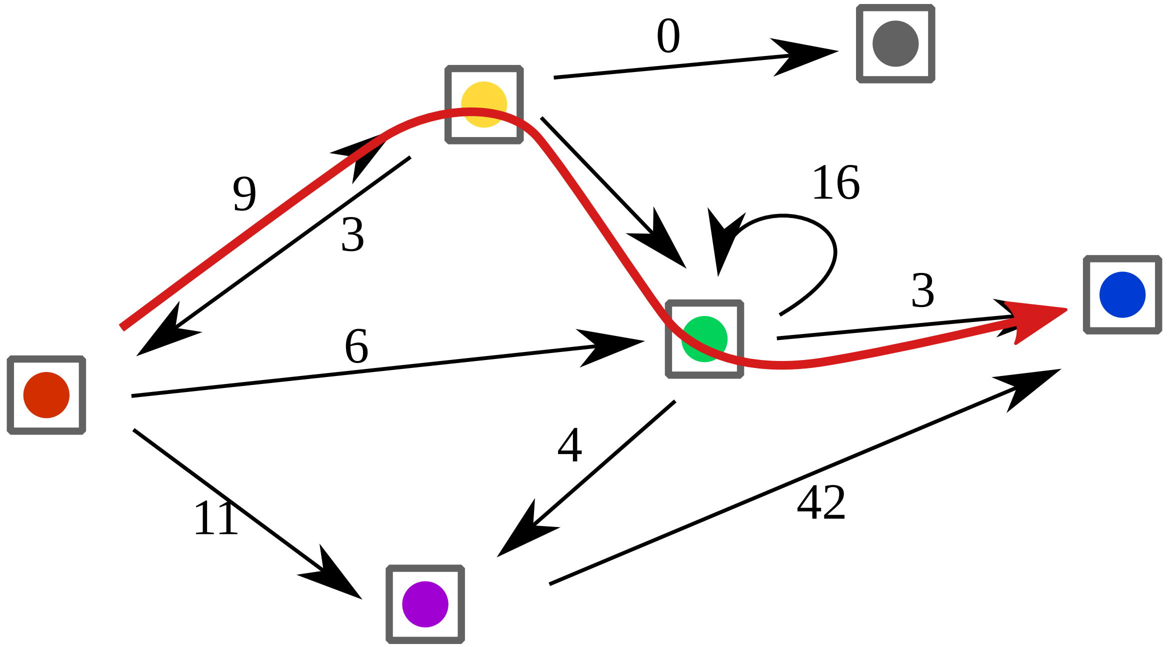
Determine a Plan

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



Plan Optimization

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

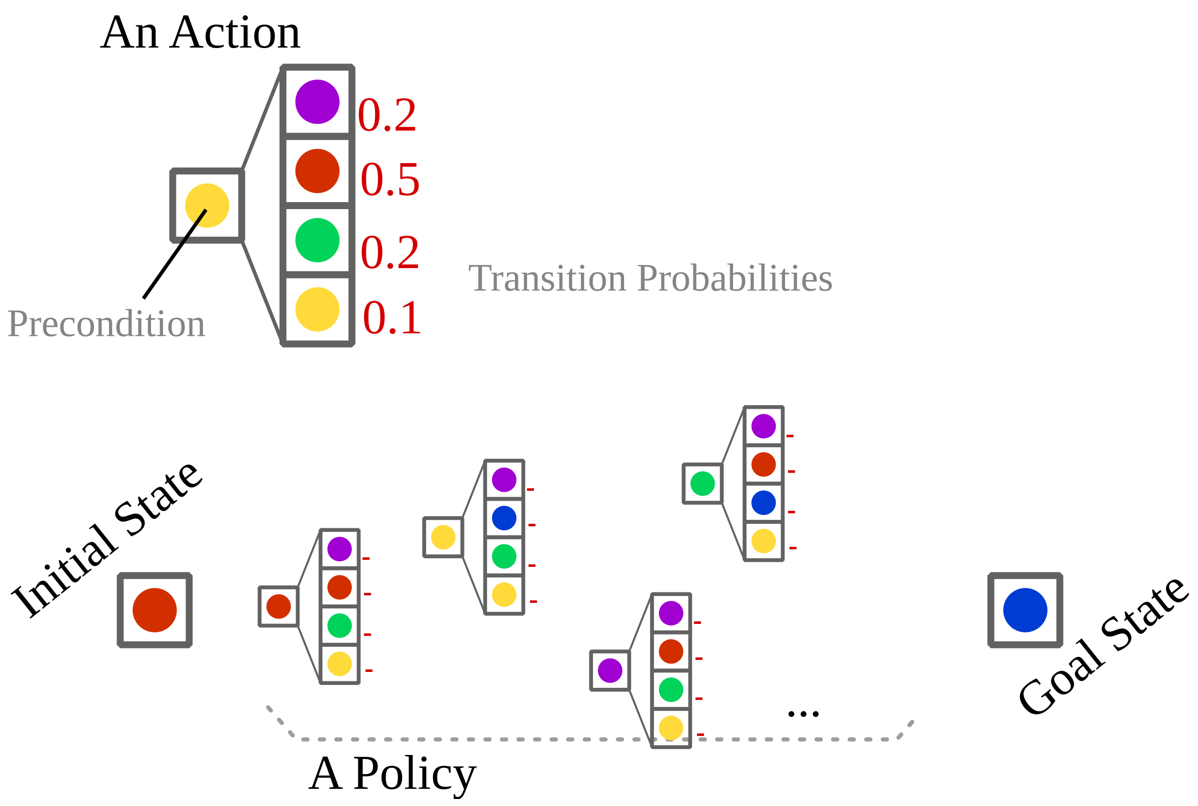


- Tipically: *Finding the shortest path from* `A` *to* `B`

Stokastic Planning

Build a *policy*:

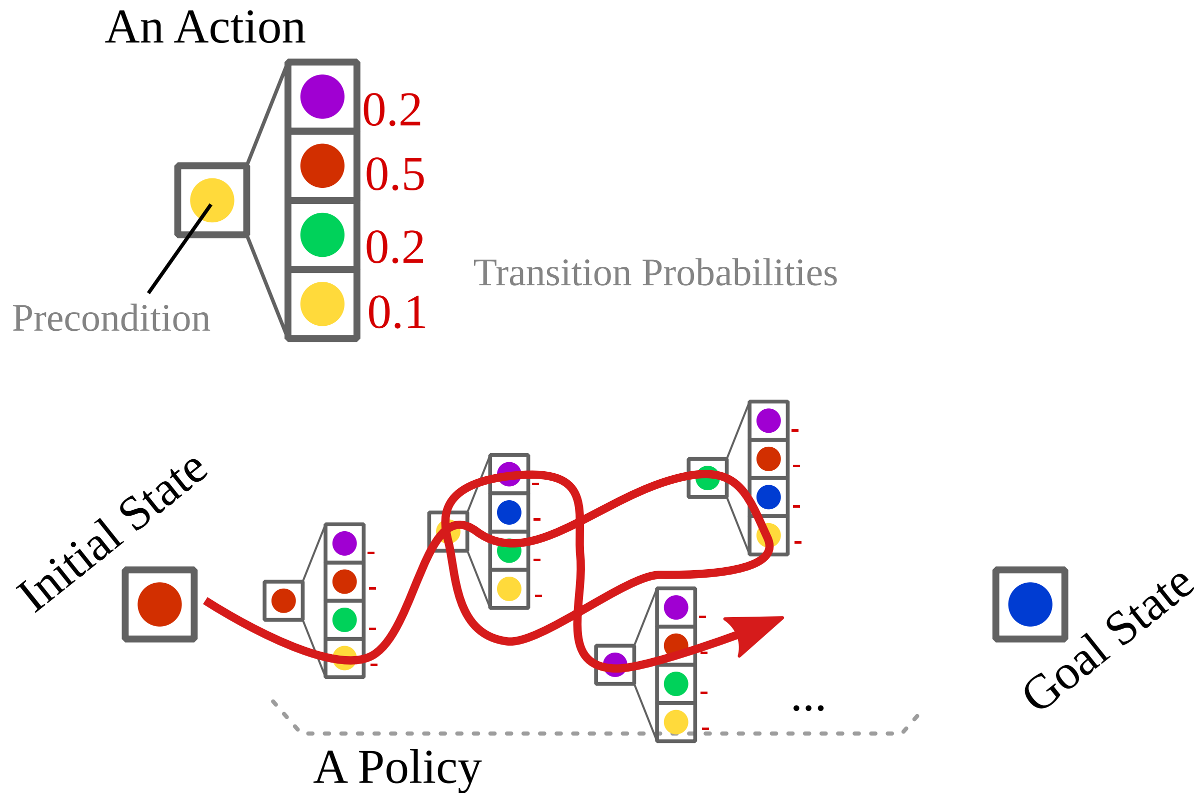
- Associate an *action* to perform *to each* reachable *state*



Stokastic Planning

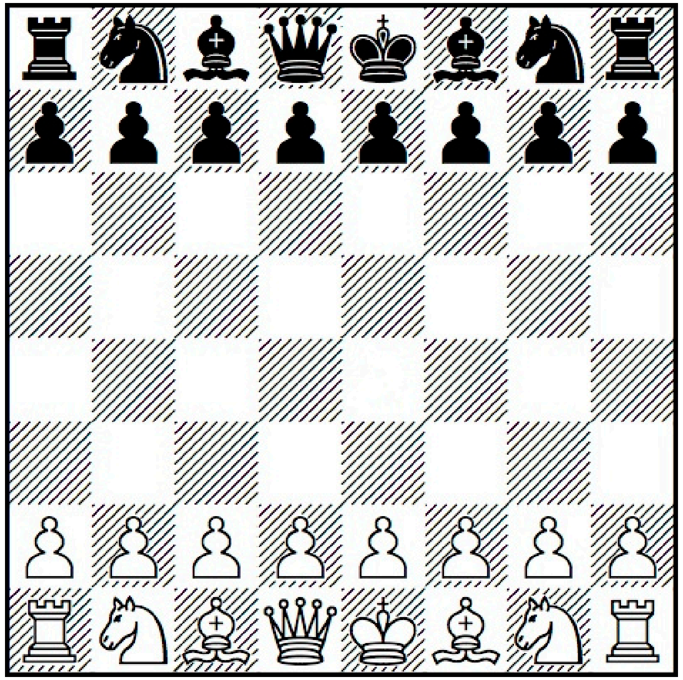
Execute a *policy*:

- Then, the effective succession of actions remains stochastic



Game Theory

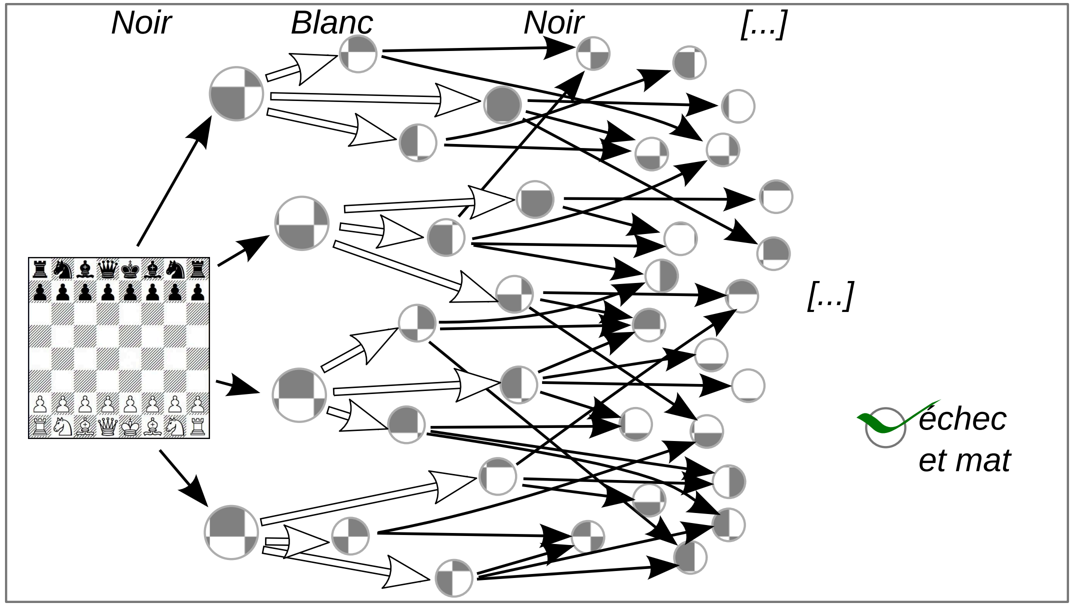
Few entities (players) control a system (with different goals)



- 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**

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Evaluate a complexity

- **Number of States** or configurations
  Number of possible snapshot of a system

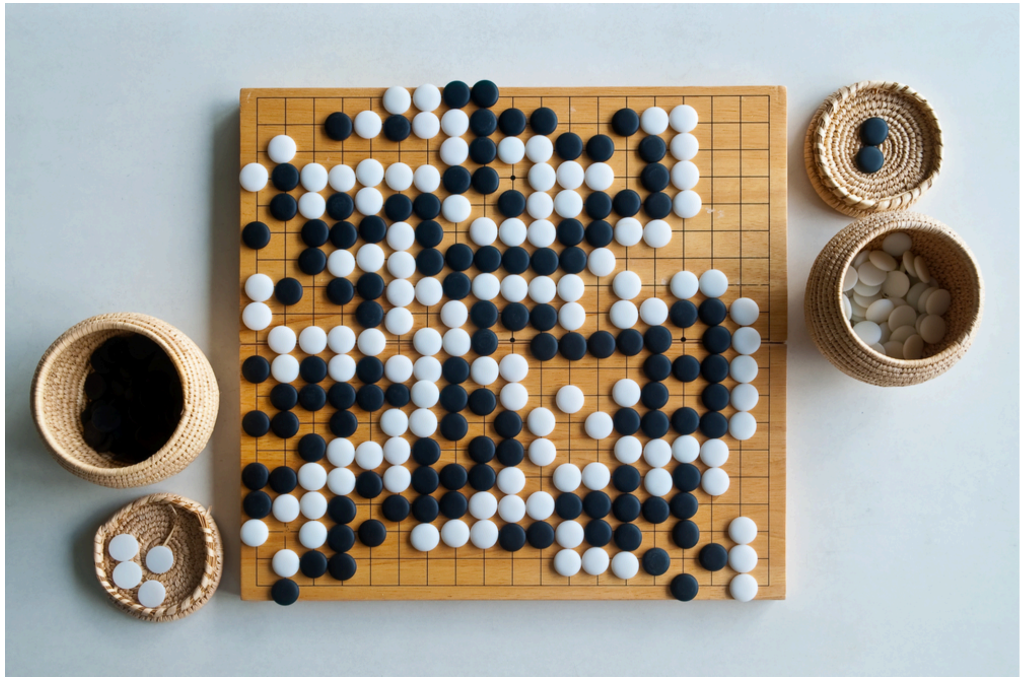
- **Number of Actions** - Number of control possibilities

- **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 : $56 \times counter = 168$

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*" $\rightarrow$ *56* posibilities

- **Horizon ?** *3*
- **Games ?** $56 \times 56 \times 56 =$ *175 616*

Game 421 - Implementation:

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

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