Why and how A.I.: an introduction

Félix Darve

lab 3SR, Grenoble INP, University Grenoble Alpes

ALERT Doctorate School 2023

“Machine learning in geomechanics”

Why and how A.I.: an introduction

Machine learning techniques as a part of A.I.

1- Why is machine learning a so deep revolution?

2 – Which fields are concerned in geomechanics?

3 – Basic research is still needed!

1 - Why is machine learning a so deep revolution?

A - An historical view to position artificial intelligent techniques in the evolution of Sapiens' methodologies to investigate Nature (since Greek period) and to develop technological tools (since Italian Renaissance),

B - The question of creativity: is machine learning just an interpolation method or more?

On the verge of a deep revolution

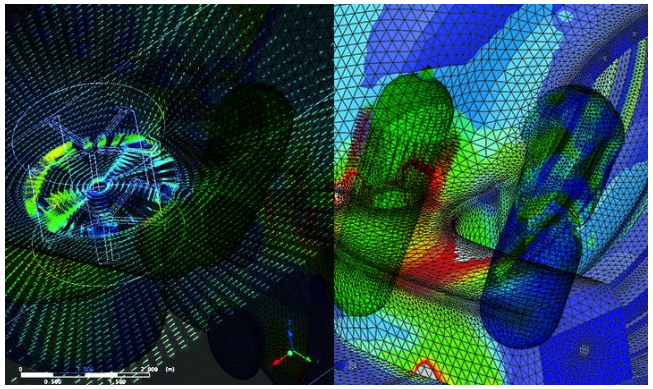
3 MAJOR STEPS

1- From – 300 before Christ to 1960 :

- Development of analytical scientific calculus,
- A simplified problem is formulated by mathematical equations, which are solved explicitely: the « **linear physics** ».
- Discovery: **the language of nature is mathematics**

- **Example** : the fall of bodies => parabolic « ballistic » equation.

On the verge of a deep revolution



2 - From 1960: development of numerical scientific computations

- A well posed problem is formulated by a set of mathematical equations, which are solved **numerically**.
- Today many available **numerical methods**: FEM, DEM, MPM, SPH, …
- **Example :** the deformation of structures – not any explicit general solution does exist. But the numerical solution provides the values of the strain and stress fields, the locations of fissures, etc … in each point of the structure.

On the verge of a deep revolution

3 - Since 2010 : development of artificial intelligence techniques

- A problem, which can be solved by accumulated experiences, is characterized by an ad hoc neural network, which is calibrated by **deep learning.**

- Each domain of human activities is potentially concerned.

Present examples: autonomous car, medical diagnosis, visual and vocal recognition, SIA robots (« Socially Interactive Agent »), ChatGPT, etc…

- **From a mathematical point of view,**

- it seems (debatable!) that the power of AI is due to:
- - the **multi-scale** nature of the geometric network giving rise to compression of the data and dimension reduction for converging towards the "solution" (**the real world has a multi-scale nature**):

  a mathematical proof of equivalence between

  "compressibility" and **"learnability".**
- - the **invariance** properties characterizing the considered problem or system and related to some groups of symmetries from a mathematical viewpoint (**the real world is led by groups of symmetries**).

1 - Why is machine learning a so deep revolution?

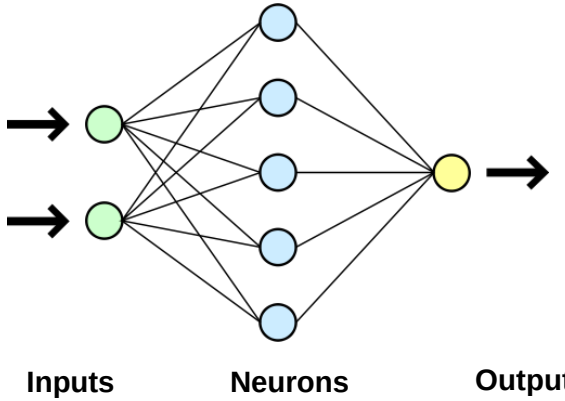
The question of creativity:

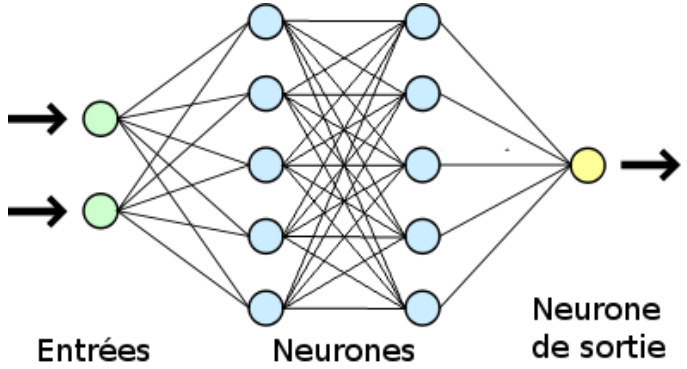
is AI an interpolation method or is it able to discover new solutions, to create novel ideas, methods, engineering systems, artistic productions, … ?

but anyway inside the global landscape produced by the data basis – as for the human brain.

AI : an artificial neuronal network

Development of a massive network

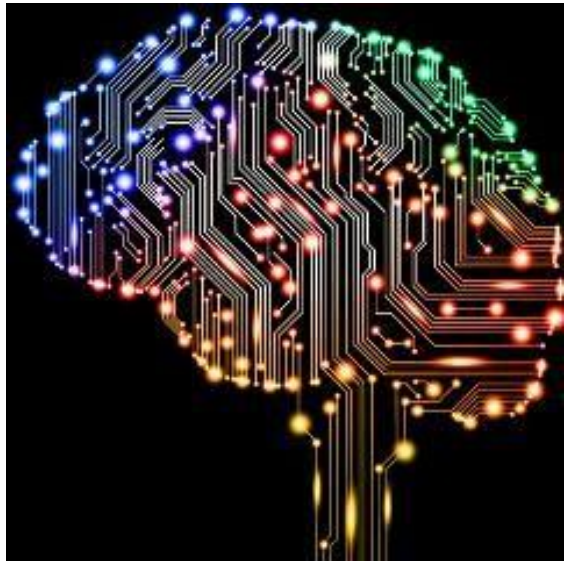




1998 : few nodes and few layers

2018 : some millions of nodes

IA : a learning



- Each link has a weight defined and determined by the knowledge of millions of cases, whose solutions are known.

  Development of **deep learning.**

The artificial intelligence software is choosing himself the cases and determines himself their solutions (**machine learning**)

Example of GO game

2 – Which fields are concerned in geomechanics?

Smart machines/robots in construction engineering

Treatment of geomechanics big data

“Automatic” design of structures and engineering works

Smart robots, machines and tools in geomechanics

Examples:

- robotics on civil engineering sites
- automatic control in a confined or human dangerous environment
- robots for engineering constructions
- etc …

Treatment and valorization of big data

Examples:

- data provided by a **very large number of sensors** on a vast spatial field or measurements performed during a long period of time: **detection of anomalous points**

- **pathologies** of engineering works (dams, dikes, …), of structures (bridges, …) and of natural sites (landslides, rockfalls, …)

- rules prescribed by « Eurocodes » (in Europe!)
- data measured by sensors (« **big data** »):
  - deformations, stresses,
  - displacements, rotations,
  - Interstitial water pressures,
  - temperatures, etc. …
- outputs (comparison to « **digital twins** »):
  - critical points (fissures, water leakages, settlements, etc.)
  - pathology analysis
  - measures to be taken

- **unsupervised machine learning** applied to DEM computations to detect the rising of internal self-organized patterns, …

The “automatic” design of structures and engineering works

Examples:

- **Constitutive relations** can be calibrated and “replaced” by machine learning codes taking into account thermodynamics constraints (definite positiveness of hyperelasticity (Stanford) or positive dissipation in elasto-plasticity (I. Stefanou))
- **“Data driven”** codes, properly trained, can simulate numerically a given class of boundary value problems and give “predictions”
- **Limits:**

- very loosely structured data (needing in principle an “infinite” data basis), which can not be compressed , so not learned,

- problems pathologically sensible to initial conditions without any asymptotic solution, for which only partial probabilistic solutions exist (as in meteorology with the “butterfly wing” effect).

- Next frontier:
- artificial consciousness ?
- “consciousness = reportability”
- “On dispose des technologies pour pirater l’être humain” Yuval Noah Harari

3 – Basic research is still needed!

2 examples presently in progress:

- Geometrisation of rheology (J. Lerbet et al.)

A full intrinsic approach of constitutive relations:

first results for hypoelasticity, hyperelasticity and second order work criterion of instability.

- Granular thermodynamics (F. Nicot et al.)

Energy is one of the basic entity ruling this universe. Entropy characterizes the irreversibility and the time arrow:

first results about shear bands as optimal dissipative structures and the configurational entropy of granular media.