Course 2: Supervised Learning

IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

2024-02-14

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Summary

Last session

1. AI definition
2. Applications
3. Deep learning
4. Open issues

Today's session

- Learning from labeled examples
- Challenges of supervised learning

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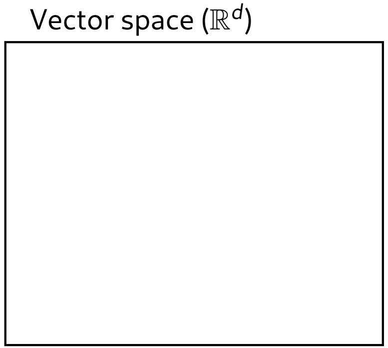

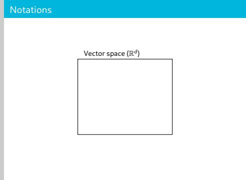

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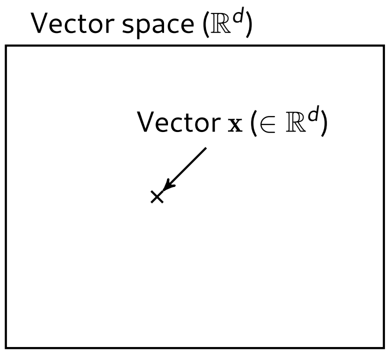
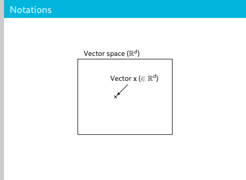
Notations





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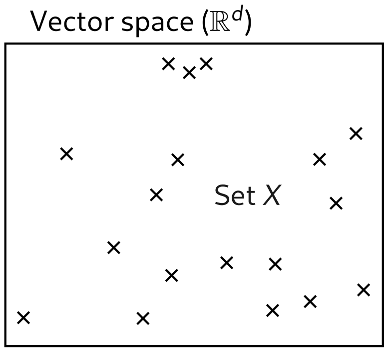

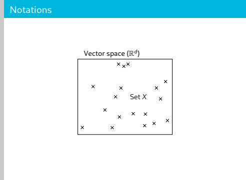

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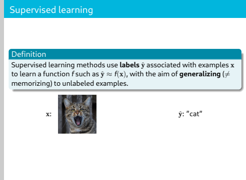
Definition

Supervised learning methods use **labels** $\hat{\mathbf{y}}$ associated with examples $\mathbf{x}$ to learn a function f such as $\hat{\mathbf{y}} \approx f(\mathbf{x})$, with the aim of **generalizing** ($\neq$ memorizing) to unlabeled examples.

$\mathbf{x}$: 

$\hat{\mathbf{y}}$: "cat"



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- Give here a few examples of regression tasks (predicting the price of a product in the stock market, the age of a person based on his/her face, ...) and classification tasks (recognizing apples versus oranges).
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Goal of supervised learning:

learning the mapping function $f()$

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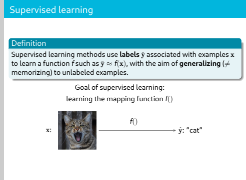

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- **Regression** ($\mathbf{y}$ is scalar)
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  - Pattern recognition,
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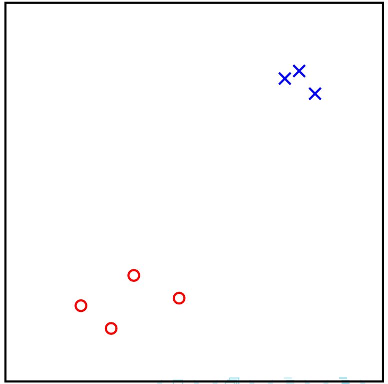

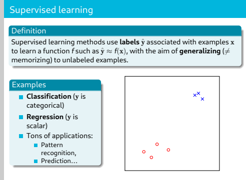

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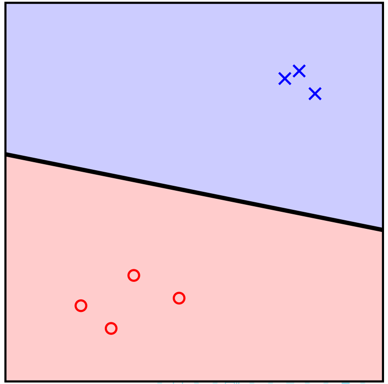

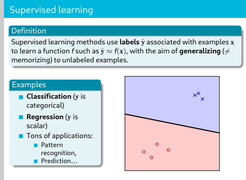

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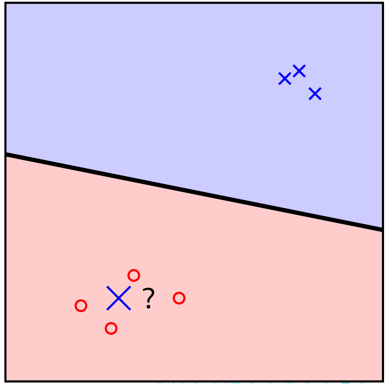

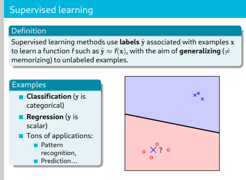

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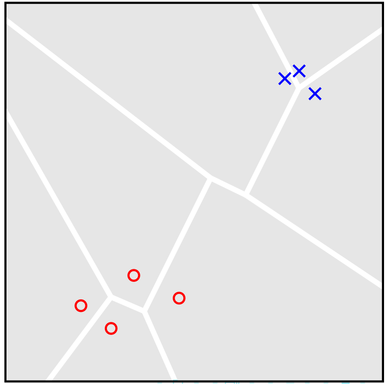

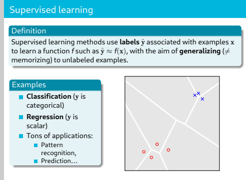

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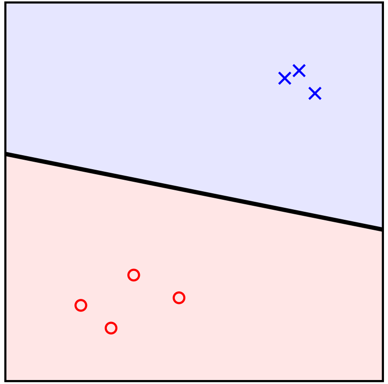
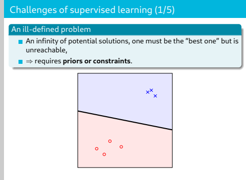
Challenges of supervised learning (1/5)

An ill-defined problem

- An infinity of potential solutions, one must be the “best one” but is unreachable,
- $\Rightarrow$ requires **priors or constraints**.





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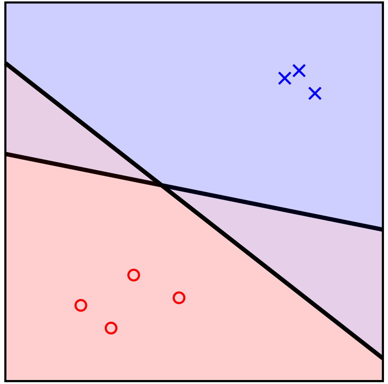

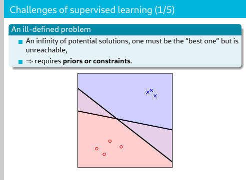

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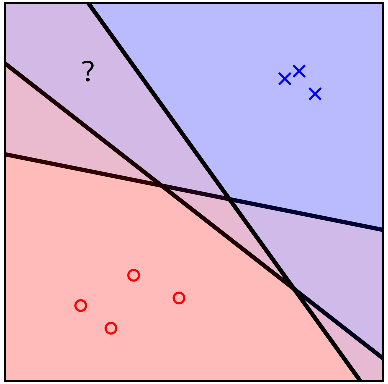

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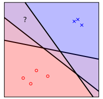

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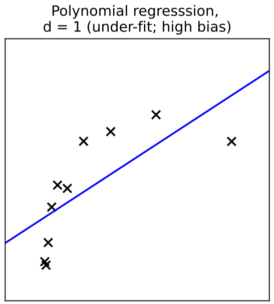
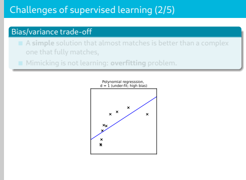
Bias/variance trade-off

- A **simple** solution that almost matches is better than a complex one that fully matches,
- Mimicking is not learning: **overfitting** problem.





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In the second part, learning curves are presented, with the goal to illustrate overfitting. The diagram on the left shows the error (in regression or classification). The X axis is illustrative, it doesn't correspond to something specific (although one could imagine it to correspond to order of a polynomial, epochs of training a neural net, ...) but it illustrates the situations of underfitting and overfitting.

Cross-validation (https://en.wikipedia.org/wiki/Cross-validation_(statistics)).

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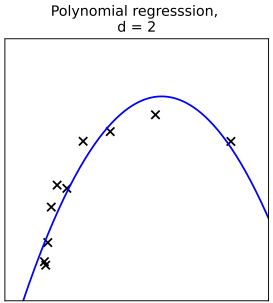

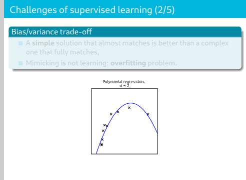

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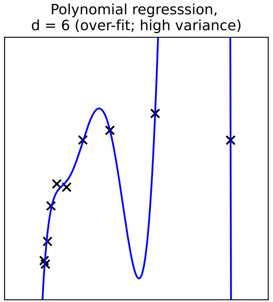

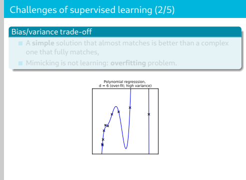

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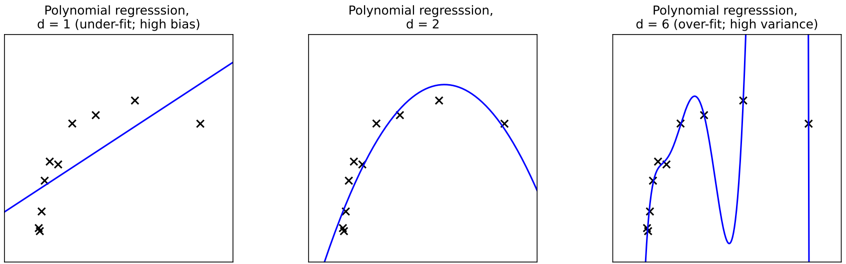

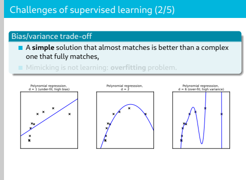

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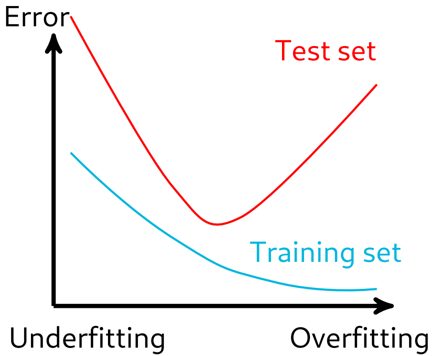
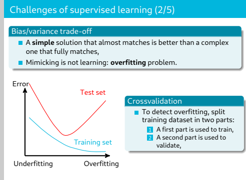


Crossvalidation

- To detect overfitting, split training dataset in two parts:
  1. A first part is used to train,
  2. A second part is used to validate,



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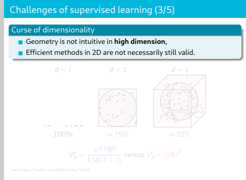
Challenges of supervised learning (3/5)

Curse of dimensionality

- Geometry is not intuitive in **high dimension**,
- Efficient methods in 2D are not necessarily still valid.

$$V_d^s = \frac{\pi^{d/2} R^d}{\Gamma(d/2+1)} \text{ versus } V_d^c = (2R)^d$$

see https://youtu.be/dZrGXYty3qc?t=533

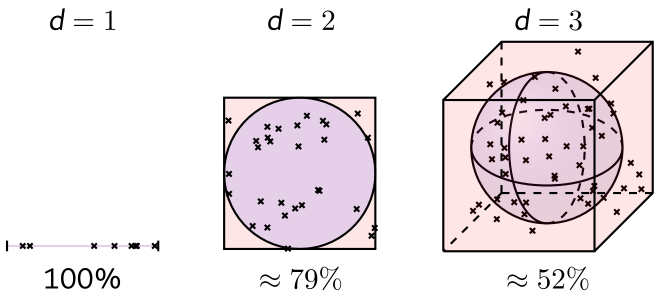


The point here is to show that when the dimension increases, the space tends to be more and more "empty". V_d^s is the volume of the hypershpere, and V_d^c is the volume of the hypercube. The crosses in the different figures are generated by each coordinates following a uniform distribution $\mathcal{U}(0, R)$ (so on average they have a value of $R/2$). When d increases, the ratio between the hypersphere and the hypercube becomes smaller and smaller, so that the majority of the volume of the hypercube lies in the corners. Therefore, the intuitions we have easily in 2D are not valid anymore, so we can imagine why it is difficult to build good classifiers in high dimensions.

Challenges of supervised learning (3/5)

Curse of dimensionality

- Geometry is not intuitive in **high dimension**,
- Efficient methods in 2D are not necessarily still valid.



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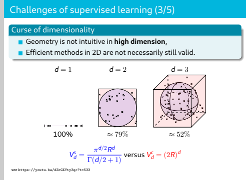

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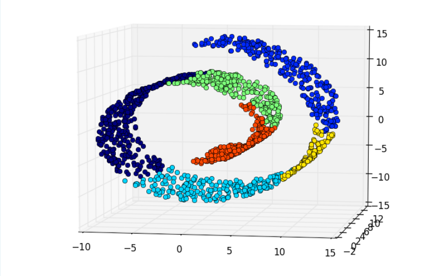
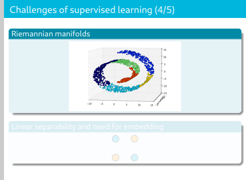
Challenges of supervised learning (4/5)

Riemannian manifolds



Linear separability and need for embedding



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Bottom part : just explain the fact that even in very simple cases, there is no way to find a linear separator.

Challenges of supervised learning (4/5)

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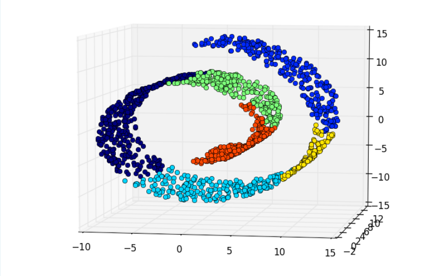

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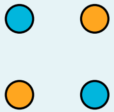

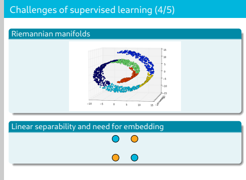

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Challenges of supervised learning (5/5)

Computation time

Example on ImageNet, simply going through all images:

- $n = 10.000.000$, $d \approx 1.000.000$,
- $\approx 10^{13}$ elementary operations,
- $\approx$ 2h45 on a modern processor.

Scalability

- Finding the best solution to a problem would be feasible with unlimited computation time,
- But searching through the space of possible functions is often **untractable**,
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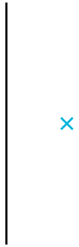

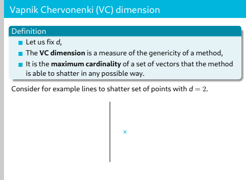

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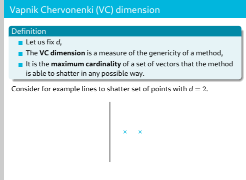

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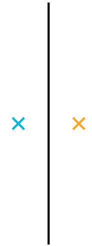

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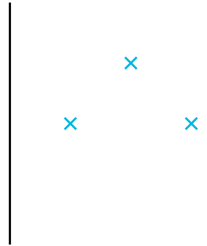

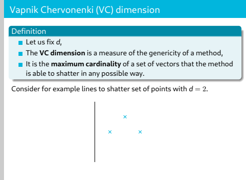

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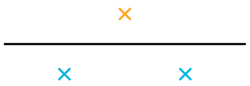

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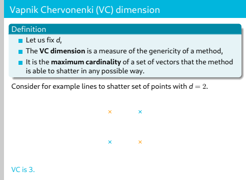

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The case of deep learning in classification

Inputs/outputs

- Often: inputs are **raw signals** or **feature vectors**,
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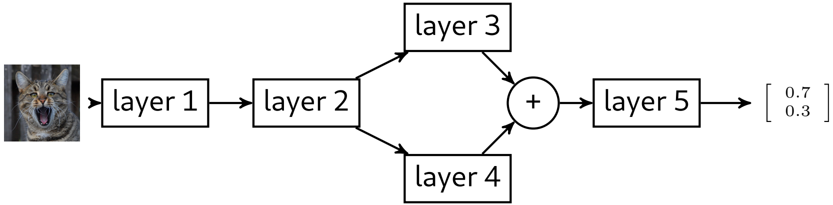

2024-02-14

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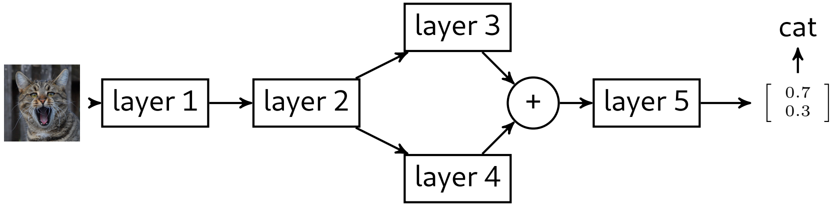

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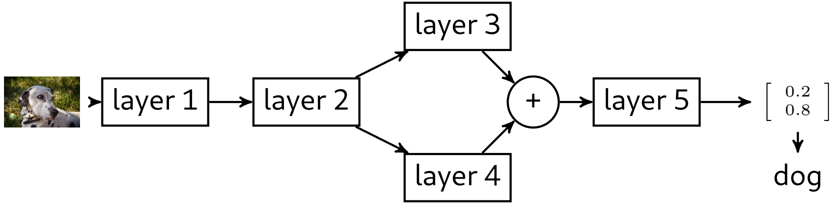

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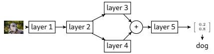

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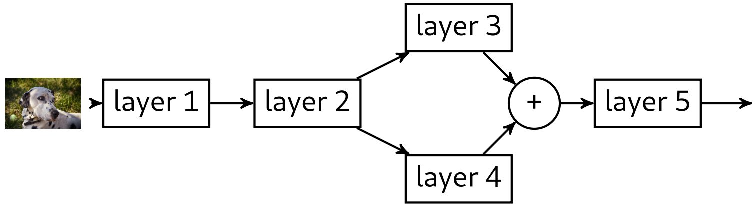

$$\begin{bmatrix} 0.2 \\ 0.8 \end{bmatrix} \neq \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

Loss and targets

- Labels are encoded as one-hot-bit vectors and called **targets**,
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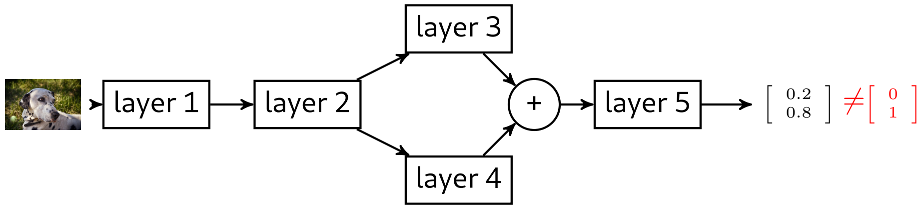

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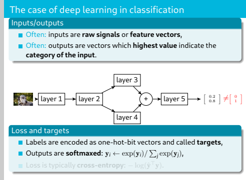

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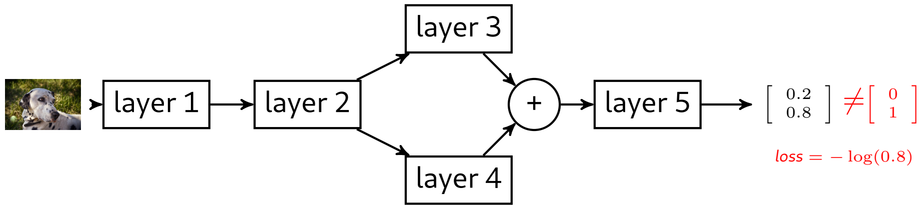

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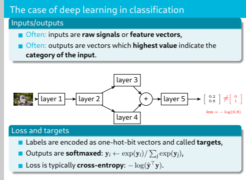
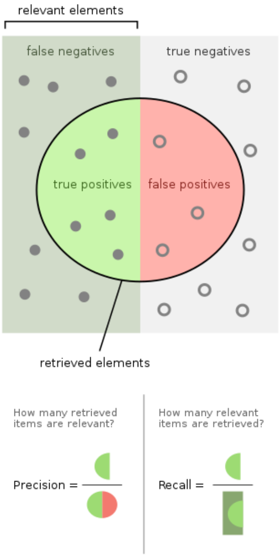
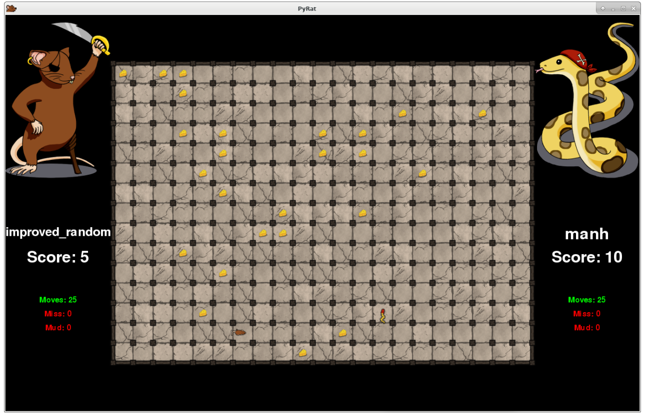


Metrics

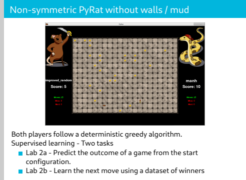
In supervised learning : per class metric





Both players follow a deterministic greedy algorithm.
Supervised learning - Two tasks

- Lab 2a - Predict the outcome of a game from the start configuration.
- Lab 2b - Learn the next move using a dataset of winners



Here, we continue the ”fil rouge” that will be followed during the whole course.
Ask the students ”Can someone remind me what is the simplest deterministic greedy approach that can be taken by a player ?”. The answer being ”always take the closest piece of cheese”.
For the first task :
The start configuration is the location of the pieces of cheese.
There are three possible outcomes : win python, win rat, and draw. So the chance level (expected accuracy of a random classifier) is 30 percent.
For the second task : There are four possible moves.

Lab Session 2 and assignments for Session 3

Lab Supervised Learning

- Basics of machine learning using sklearn (including new definitions / concepts)
- Tests on PyRat datasets : winner prediction task

Project 1 (P1)

You will choose a supervised learning method. You have to prepare a Jupyter Notebook on this method, including:

- A brief description of the theory behind the method,
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Here, it is important to tell them that we expect them to think about interpreting the result on the pyrat datasets. In addition, there are definitions in the Lab Session (accuracy, precision, recall and f1 score) that are important to learn.

IMPORTANT : tell them to remember that they have COMPLETE CONTROL on the generation of the pyrat datasets (size of the maze, number of pieces of cheese, ...). So they can use that to explore the problem.