

# **Introduction to Machine Learning**

## **Introduction: Components of a Learner**

[compstat-lmu.github.io/lecture\\_i2ml](https://compstat-lmu.github.io/lecture_i2ml)

# COMPONENTS OF A LEARNER

Nearly all supervised learning algorithms can be described in terms of three components:

**Learning = Hypothesis Space + Risk + Optimization**

- **Hypothesis Space:** Defines (and restricts!) what kind of model  $f$  can be learned from the data.
- **Risk:** A metric that quantifies how well a specific model performs on a given data set. This defines how to compare observed values to predictions and allows us to rank candidate models in order to choose the best one.
- **Optimization:** Defines how to search for the best model in the **hypothesis space**, typically guided by the metric used for the **risk**.

# HYPOTHESIS SPACE + RISK + OPTIMIZATION

By decomposing learners into these components

- we have a framework to understand how they work
- we can more easily evaluate in which settings they may be more or less suitable
- we can tailor learners to specific problems by clever choice of each of the three components

# SUPERVISED LEARNING, FORMALIZED:

## A learner

- receives a **training set**  $\mathcal{D} \in \mathcal{X} \times \mathcal{Y}$
- and uses an **optimization** procedure to find

$$\hat{f} = \arg \min_{f \in \mathcal{H}} \mathcal{R}_{\text{emp}}(f).$$

- for a given **hypothesis class**  $\mathcal{H}$  of **models**  $f : \mathcal{X} \rightarrow \mathbb{R}^g$
- based on a **risk** function  $\mathcal{R}_{\text{emp}}(f)$  that quantifies the performance of  $f \in \mathcal{H}$  on  $\mathcal{D}$ .

(This does not cover all special cases, but it's a useful framework for most supervised ML problems.)

# COMPONENTS OF A LEARNER

**Hypothesis Space :** {  
Step functions  
Linear functions  
Sets of rules  
Neural networks  
Voronoi tessellations  
...

**Risk :** {  
Mean squared error  
Misclassification rate  
Negative log-likelihood  
Information gain  
...

**Optimization :** {  
Analytic solution  
Gradient descent  
Combinatorial optimization  
Genetic algorithms  
...