

# Introduction to Machine Learning

## ML-Basics: In a Nutshell



### Learning goals

- Understand fundamental goal of supervised machine learning
- Know concepts of task, model, parameter, learner, loss function, and empirical risk minimization

# WHAT IS ML?

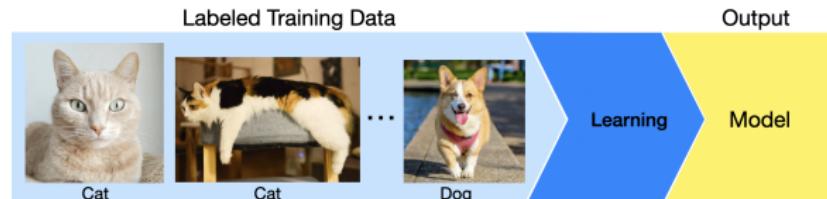
"A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E."

*Tom Mitchell, Carnegie Mellon University, 1998*

⇒ 99 % of this lecture is about **supervised learning**:

Training

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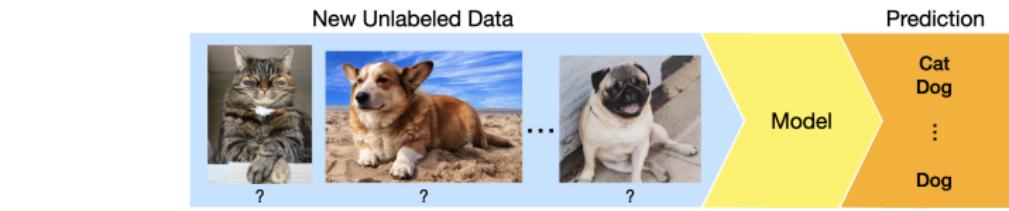
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# WHAT IS ML?

Prediction



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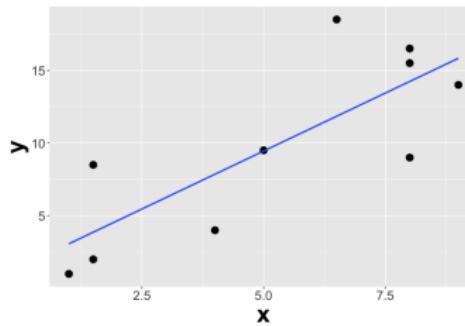
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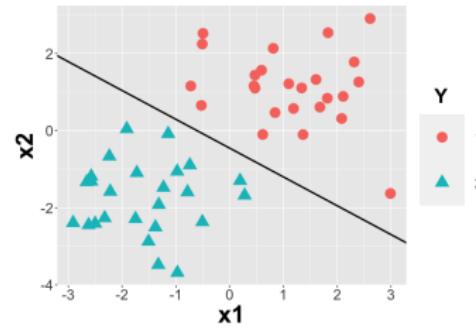
# TASKS

- Supervised tasks are labeled data situations where the goal is to learn the functional relationship between inputs (features) and output (target)
- We distinguish between **regression** and **classification** tasks, depending on whether the target is **numerical** or **categorical**

**Regression:** Target is **numerical**, e.g., predict days a patient has to stay in hospital

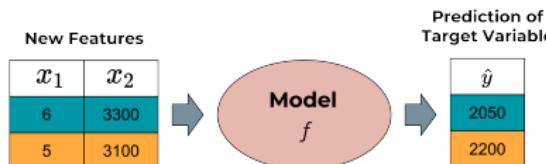


**Classification:** Target is **categorical**, e.g., predict one of two risk categories for a life insurance customer



# MODELS AND PARAMETERS

- A model is a function that maps features to predicted targets

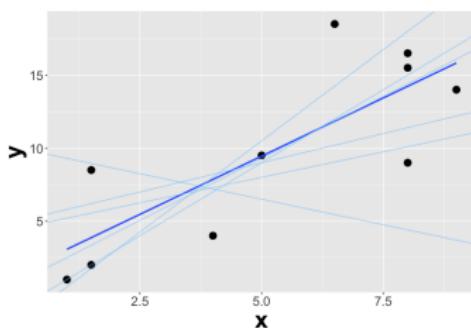


- For finding the model that describes the relation between features and target best, one needs to restrict the set of all possible functions
- This restricted set of functions is called **hypothesis space**. E.g., one could consider only simple linear functions as hypothesis space
- Functions are fully determined by parameters. E.g. in the case of linear functions,  $y = \theta_0 + \theta_1 x$ , the parameters  $\theta_0$  (intercept) and  $\theta_1$  (slope) determine the relationship between  $y$  and  $x$
- Finding the optimal model means finding the optimal set of parameters

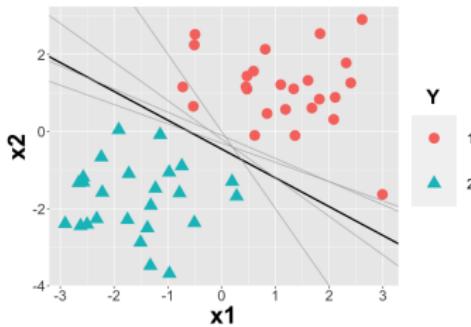
# LEARNER

- Learns automatically the relation between features and target – given a set of training data
- Learner picks the best element of the **hypothesis space**, i.e., the function that fits the training data best

## Regression:

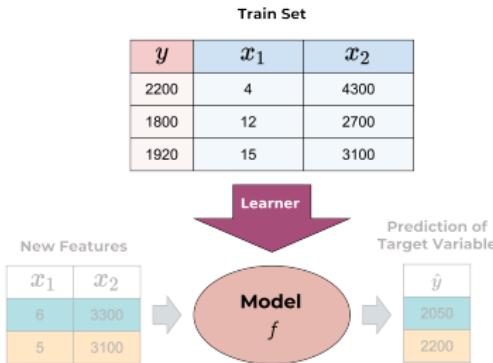


## Classification:



# LEARNER

- Learner uses labeled training data to learn a model  $f$ . This model is applied to new data for predicting the target variable



# LOSS AND RISK MINIMIZATION

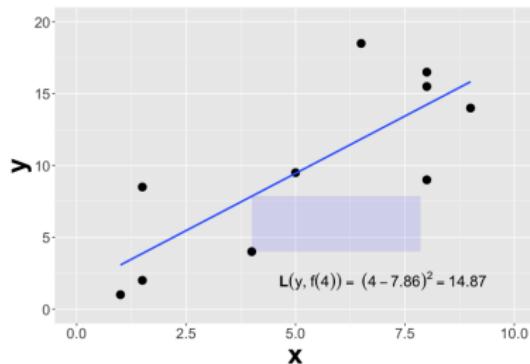
- Loss: Measured pointwise for each observation, e.g.,  $L_2$ -loss

$$L(y, f(\mathbf{x})) = (y - f(\mathbf{x}))^2$$

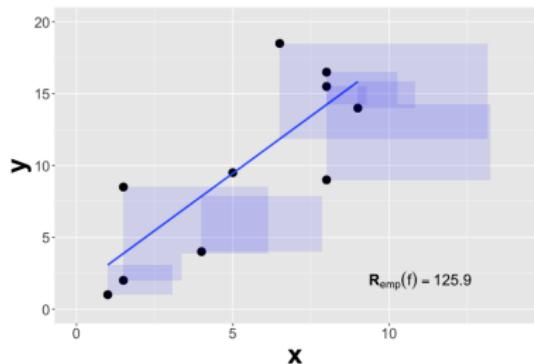
- Risk: Measured for entire model. Sums up pointwise losses.

$$\mathcal{R}_{\text{emp}}(f) = \sum_{i=1}^n L(y^{(i)}, f(\mathbf{x}^{(i)}))$$

Squared **loss** of one **observation**.



Empirical **risk** of entire **model**



# EMPIRICAL RISK MINIMIZATION

- The risk surface visualizes the empirical risk for all possible parameter values of the parameter vector  $\theta$
- Minimizing the empirical risk is usually done by numerical optimization

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

