Algorithmic Learning Theory

WS 23/24, RWTH Aachen

October 11, 2023

Contents

Introduction

These notes summarize the course about the theoretical foundations of machine learning. It will be concerned with the following key topics and questions:

- **Statistical Learning theory**, concerned for example with expressing how much data is needed in order to learn, how (statistical) guarantees can be given, etc.
- **Expressiveness**, telling which functions can be expressed with our learning algorithms (e.g., multilayer perceptron, NN, ...), whether those suffice to describe reality and also what happens if the models are made richer.
- **Algorithms and complexity**, involved with finding good models efficiently, telling what algorithms are good, and which theoretic limitations their complexity has.

1 Statistical learning framework

Let's start with the basic formal framework describing statistical learning theory.

Papaya example

We will start with an introductory example concerned with papayas. The task in our example is the following:

- We want to predict whether a tropical fruit (here a papaya) is tasty or not. | Boolean classification problem
- The decision shall be based on observations that we can make from the outside.
- We get a sample of papayas to try, which we will use as our *training set*. | Supervised learning setting

Figure 1: Papaya with different features

As our first step, we need to select features. Based for example on previous experience with other fruits, we decide to base our decision on these two features of papayas: | Feature selection

- Colour, ranging from green through yellow and red to brown
- Softness, ranging from hard to mushy

When we fill a diagram with our training data to visualize the features and the correct labels.

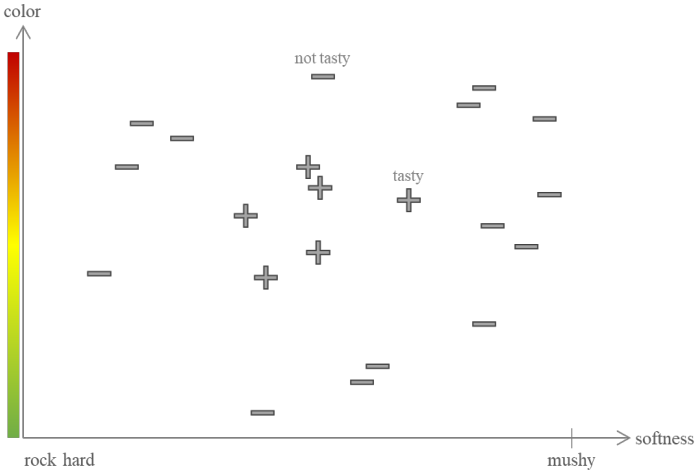

Figure 2: Papaya features

Next, we select a model and try to fit it optimally with our training data. For that, parameter fitting is applied. Consider for example a simple parametric model where the features have to lie in a certain range.

| parametric model

- Color: $[c_{\min}, c_{\max}]$
- Softness: $[s_{\min}, s_{\max}]$

} 4 parameters to be estimated
goal: make resulting hypothesis explaining data best

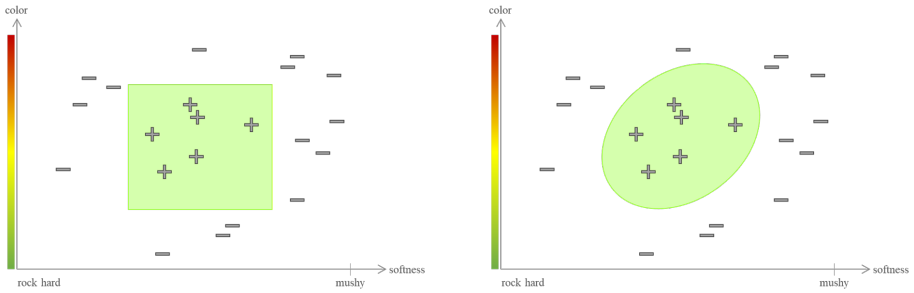

Figure 3: Papaya features