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Introduction

*Statistical learning* plays a key role in many areas of science, ﬁnance and industry. Here are some examples of learning problems:

Predict whether a patient, hospitalized due to a heart attack, will have a second heart attack. The prediction is to be based on demo- graphic, diet and clinical measurements for that patient.

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Predict the price of a stock in 6 months from now, on the basis of company performance measures and economic data.

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Identify the numbers in a handwritten ZIP code, from a digitized image.

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Estimate the amount of glucose in the blood of a diabetic person, from the infrared absorption spectrum of that person’s blood.

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Identify the risk factors for prostate cancer, based on clinical and demographic variables.

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The science of learning plays a key role in the ﬁelds of statistics, data mining and artiﬁcial intelligence, intersecting with areas of engineering and other disciplines.

This book is about learning from data. In a typical scenario, we have an outcome measurement, usually quantitative (such as a stock price) or categorical (such as heart attack/no heart attack), that we wish to predict based on a set of *features* (such as diet and clinical measurements). We have a *training set* of data, in which we observe the outcome and feature

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TABLE 1.1. *Average percentage of words or characters in an email message equal to the indicated word or character. We have chosen the words and characters showing the largest diﬀerence between* spam *and* email*.*

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | george | you | your | hp | free | hpl | ! | our | re | edu | remove |
| spam | 0.00 | 2.26 | 1.38 | 0.02 | 0.52 | 0.01 | 0.51 | 0.51 | 0.13 | 0.01 | 0.28 |
| email | 1.27 | 1.27 | 0.44 | 0.90 | 0.07 | 0.43 | 0.11 | 0.18 | 0.42 | 0.29 | 0.01 |

measurements for a set of objects (such as people). Using this data we build a prediction model, or *learner*, which will enable us to predict the outcome for new unseen objects. A good learner is one that accurately predicts such an outcome.

The examples above describe what is called the *supervised learning* prob- lem. It is called “supervised” because of the presence of the outcome vari- able to guide the learning process. In the *unsupervised learning problem*, we observe only the features and have no measurements of the outcome. Our task is rather to describe how the data are organized or clustered. We devote most of this book to supervised learning; the unsupervised problem is less developed in the literature, and is the focus of Chapter 14.

Here are some examples of real learning problems that are discussed in this book.

*Example 1: Email Spam*

The data for this example consists of information from 4601 email mes- sages, in a study to try to predict whether the email was junk email, or “spam.” The objective was to design an automatic spam detector that could ﬁlter out spam before clogging the users’ mailboxes. For all 4601 email messages, the true outcome (email type) email or spam is available, along with the relative frequencies of 57 of the most commonly occurring words and punctuation marks in the email message. This is a supervised learning problem, with the outcome the class variable email/spam. It is also called a *classiﬁcation* problem.

Table 1.1 lists the words and characters showing the largest average diﬀerence between spam and email.

Our learning method has to decide which features to use and how: for example, we might use a rule such as

if (%george < 0.6) & (%you > 1.5) then spam

else email.

Another form of a rule might be:

if (0.2 %you 0.3 %george) > 0 then spam

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else email.