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# DENSITY ESTIMATION FOR STATISTICS AND DATA ANALYSIS

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## I. INTRODUCTION

### I.1. What is density estimation?

The *probability density function* is a fundamental concept in statistics. Consider any random quantity  $X$  that has probability density function  $f$ . Specifying the function  $f$  gives a natural description of the distribution of  $X$ , and allows probabilities associated with  $X$  to be found from the relation

$$P(a < X < b) = \int_a^b f(x)dx \quad \text{for all } a < b.$$

Suppose, now, that we have a set of observed data points assumed to be a sample from an unknown probability density function. *Density estimation*, as discussed in this book, is the construction of an estimate of the density function from the observed data. The two main aims of the book are to explain how to estimate a density from a given data set and to explore how density estimates can be used, both in their own right and as an ingredient of other statistical procedures.

One approach to density estimation is *parametric*. Assume that the data are drawn from one of a known parametric family of distributions, for example the normal distribution with mean  $\mu$  and variance  $\sigma^2$ . The density  $f$  underlying the data could then be estimated by finding estimates of  $\mu$  and  $\sigma^2$  from the data and substituting these estimates into the formula for the normal density. In this book we shall not be considering parametric estimates of this kind; the approach will be more *non-parametric* in that less rigid assumptions will be made about the distribution of the observed data. Although it will be assumed that the distribution has a probability density  $f$ , the data will be allowed to speak for themselves in determining the estimate of  $f$  more than would be the case if  $f$  were constrained to fall in a given parametric family.

Density estimates of the kind discussed in this book, were first proposed by Fix and Hodges (1951) as a way of freeing

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