Python Data Analytics

With Pandas, NumPy, and Matplotlib

Second Edition

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About the Technical Reviewer

Raul Samayoa is a senior software developer and machine learning specialist with many years of experience in the financial industry. An MSc graduate from the Georgia Institute of Technology, he's never met a neural network or dataset he did not like. He's fond of evangelizing the use of DevOps tools for data science and software development.

Raul enjoys the energy of his hometown of Toronto, Canada, where he runs marathons, volunteers as a technology instructor with the University of Toronto coders, and likes to work with data in Python and R.

CHAPTER 1

An Introduction to Data Analysis

In this chapter, you begin to take the first steps in the world of data analysis, learning in detail about all the concepts and processes that make up this discipline. The concepts discussed in this chapter are helpful background for the following chapters, where these concepts and procedures will be applied in the form of Python code, through the use of several libraries that will be discussed in just as many chapters.

Data Analysis

In a world increasingly centralized around information technology, huge amounts of data are produced and stored each day. Often these data come from automatic detection systems, sensors, and scientific instrumentation, or you produce them daily and unconsciously every time you make a withdrawal from the bank or make a purchase, when you record various blogs, or even when you post on social networks.

But what are the data? The data actually are not information, at least in terms of their form. In the formless stream of bytes, at first glance it is difficult to understand their essence if not strictly the number, word, or time that they report. Information is actually the result of processing, which, taking into account a certain dataset, extracts some conclusions that can be used in various ways. This process of extracting information from raw data is called *data analysis*.

The purpose of data analysis is to extract information that is not easily deducible but that, when understood, leads to the possibility of carrying out studies on the mechanisms of the systems that have produced them, thus allowing you to forecast possible responses of these systems and their evolution in time.

F. Nelli, *Python Data Analytics*, https://doi.org/10.1007/978-1-4842-3913-1_1

Starting from a simple methodical approach on data protection, data analysis has become a real discipline, leading to the development of real methodologies generating *models*. The model is in fact the translation into a mathematical form of a system placed under study. Once there is a mathematical or logical form that can describe system responses under different levels of precision, you can then make predictions about its development or response to certain inputs. Thus the aim of data analysis is not the model, but the quality of its *predictive power*.

The predictive power of a model depends not only on the quality of the modeling techniques but also on the ability to choose a good dataset upon which to build the entire data analysis process. So the *search for data*, their *extraction*, and their subsequent *preparation*, while representing preliminary activities of an analysis, also belong to data analysis itself, because of their importance in the success of the results.

So far we have spoken of data, their handling, and their processing through calculation procedures. In parallel to all stages of processing of data analysis, various methods of *data visualization* have been developed. In fact, to understand the data, both individually and in terms of the role they play in the entire dataset, there is no better system than to develop the techniques of graphic representation capable of transforming information, sometimes implicitly hidden, in figures, which help you more easily understand their meaning. Over the years lots of display modes have been developed for different modes of data display: the *charts*.

At the end of the data analysis process, you will have a model and a set of graphical displays and then you will be able to predict the responses of the system under study; after that, you will move to the test phase. The model will be tested using another set of data for which you know the system response. These data are, however, not used to define the predictive model. Depending on the ability of the model to replicate real observed responses, you will have an error calculation and knowledge of the validity of the model and its operating limits.

These results can be compared with any other models to understand if the newly created one is more efficient than the existing ones. Once you have assessed that, you can move to the last phase of data analysis—*deployment*. This consists of implementing the results produced by the analysis, namely, implementing the decisions to be taken based on the predictions generated by the model and the associated risks.

Data analysis is well suited to many professional activities. So, knowledge of it and how it can be put into practice is relevant. It allows you to test hypotheses and to understand more deeply the systems analyzed.

Knowledge Domains of the Data Analyst

Data analysis is basically a discipline suitable to the study of problems that may occur in several fields of applications. Moreover, data analysis includes many tools and methodologies that require good knowledge of computing, mathematical, and statistical concepts.

A good data analyst must be able to move and act in many different disciplinary areas. Many of these disciplines are the basis of the methods of data analysis, and proficiency in them is almost necessary. Knowledge of other disciplines is necessary depending on the area of application and study of the particular data analysis project you are about to undertake, and, more generally, sufficient experience in these areas can help you better understand the issues and the type of data needed.

Often, regarding major problems of data analysis, it is necessary to have an interdisciplinary team of experts who can contribute in the best possible way in their respective fields of competence. Regarding smaller problems, a good analyst must be able to recognize problems that arise during data analysis, inquire to determine which disciplines and skills are necessary to solve these problems, study these disciplines, and maybe even ask the most knowledgeable people in the sector. In short, the analyst must be able to know how to search not only for data, but also for information on how to treat that data.

Computer Science

Knowledge of computer science is a basic requirement for any data analyst. In fact, only when you have good knowledge of and experience in computer science can you efficiently manage the necessary tools for data analysis. In fact, every step concerning data analysis involves using calculation software (such as IDL, MATLAB, etc.) and programming languages (such as C ++, Java, and Python).

The large amount of data available today, thanks to information technology, requires specific skills in order to be managed as efficiently as possible. Indeed, data research and extraction require knowledge of these various formats. The data are structured and stored in files or database tables with particular formats. XML, JSON, or simply XLS or CSV files, are now the common formats for storing and collecting data, and many applications allow you to read and manage the data stored on them. When it comes to extracting data contained in a database, things are not so immediate, but you need to know the SQL query language or use software specially developed for the extraction of data from a given database.

Moreover, for some specific types of data research, the data are not available in an explicit format, but are present in text files (documents and log files) or web pages, and shown as charts, measures, number of visitors, or HTML tables. This requires specific technical expertise for the parsing and the eventual extraction of these data (called *web scraping*).

So, knowledge of information technology is necessary to know how to use the various tools made available by contemporary computer science, such as applications and programming languages. These tools, in turn, are needed to perform data analysis and data visualization.

The purpose of this book is to provide all the necessary knowledge, as far as possible, regarding the development of methodologies for data analysis. The book uses the Python programming language and specialized libraries that provide a decisive contribution to the performance of all the steps constituting data analysis, from data research to data mining, to publishing the results of the predictive model.

Mathematics and Statistics

As you will see throughout the book, data analysis requires a lot of complex math during the treatment and processing of data. You need to be competent in all of this, at least to understand what you are doing. Some familiarity with the main statistical concepts is also necessary because all the methods that are applied in the analysis and interpretation of data are based on these concepts. Just as you can say that computer science gives you the tools for data analysis, so you can say that the statistics provide the concepts that form the basis of data analysis.

This discipline provides many tools to the analyst, and a good knowledge of how to best use them requires years of experience. Among the most commonly used statistical techniques in data analysis are

- Bayesian methods
- Regression
- Clustering

Having to deal with these cases, you'll discover how mathematics and statistics are closely related. Thanks to the special Python libraries covered in this book, you will be able to manage and handle them.

Machine Learning and Artificial Intelligence

One of the most advanced tools that falls in the data analysis camp is machine learning. In fact, despite the data visualization and techniques such as clustering and regression, which should help you find information about the dataset, during this phase of research, you may often prefer to use special procedures that are highly specialized in searching patterns within the dataset.

Machine learning is a discipline that uses a whole series of procedures and algorithms that analyze the data in order to recognize patterns, clusters, or trends and then extracts useful information for data analysis in an automated way.

This discipline is increasingly becoming a fundamental tool of data analysis, and thus knowledge of it, at least in general, is of fundamental importance to the data analyst.

Professional Fields of Application

Another very important point is the domain of competence of the data (its source—biology, physics, finance, materials testing, statistics on population, etc.). In fact, although analysts have had specialized preparation in the field of statistics, they must also be able to document the source of the data, with the aim of perceiving and better understanding the mechanisms that generated the data. In fact, the data are not simple strings or numbers; they are the expression, or rather the measure, of any parameter observed. Thus, better understanding where the data came from can improve their interpretation. Often, however, this is too costly for data analysts, even ones with the best intentions, and so it is good practice to find consultants or key figures to whom you can pose the right questions.

Understanding the Nature of the Data

The object of study of data analysis is basically the data. The data then will be the key player in all processes of data analysis. The data constitute the raw material to be processed, and thanks to their processing and analysis, it is possible to extract a variety of information in order to increase the level of knowledge of the system under study, that is, one from which the data came.

When the Data Become Information

Data are the events recorded in the world. Anything that can be measured or categorized can be converted into data. Once collected, these data can be studied and analyzed, both to understand the nature of the events and very often also to make predictions or at least to make informed decisions.

When the Information Becomes Knowledge

You can speak of knowledge when the information is converted into a set of rules that helps you better understand certain mechanisms and therefore make predictions on the evolution of some events.

Types of Data

Data can be divided into two distinct categories:

- Categorical (nominal and ordinal)
- Numerical (discrete and continuous)

Categorical data are values or observations that can be divided into groups or categories. There are two types of categorical values: *nominal* and *ordinal*. A nominal variable has no intrinsic order that is identified in its category. An ordinal variable instead has a predetermined order.

Numerical data are values or observations that come from measurements. There are two types of numerical values: *discrete* and *continuous* numbers. Discrete values can be counted and are distinct and separated from each other. Continuous values, on the other hand, are values produced by measurements or observations that assume any value within a defined range.

The Data Analysis Process

Data analysis can be described as a process consisting of several steps in which the raw data are transformed and processed in order to produce data visualizations and make predictions thanks to a mathematical model based on the collected data. Then, data