Ultimate Data Science Programming in Python

Master data science libraries with 300+ programs, 2 projects, and EDA GUI tools

Saurabh Chandrakar

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Dedicated to

My parents

***Dr. Surendra Kumar Chandrakar** and*
Smt. Bhuneshwari Chandrakar
my brother
Shri Pranav Chandrakar

my sister-in-law

Smt. Silky Chandrakar

my wife

Smt. Priyanka Chandrakar

and my lovely son

Master Yathartha Chandrakar

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My parents, Dr. Surendra Kumar Chandrakar and Smt. Bhuneshwari Chandrakar, my brother, Shri Pranav Chandrakar, my sister-in-law, Silky Chandrakar, my beloved wife, Mrs. Priyanka Chandrakar, my adorable son, Yathartha Chandrakar, and all of my friends who have inspired me and given me the confidence over the years. Last but not least, I would like to express my sincere gratitude to the staff at BPB Publications for their contributions and insights that made parts of this book possible.

Preface

The purpose of this book is to introduce individuals to the dynamic field of data science in Python, unraveling the capabilities of essential libraries that drive data analysis and manipulation. For those with varied levels of programming experience, this book serves as a gateway to the intricate world of NumPy, SciPy, Matplotlib, Pandas, Polars, Seaborn, and usage of ChatGPT for all these open-source libraries. Readers will embark on a hands-on journey, navigating through a multitude of solved examples that illuminate the practical application of each library. Beginning with foundational concepts, the chapters progressively explore advanced functionalities, empowering readers to harness the full potential of these libraries. Whether it is mastering the manipulation of data with pandas, visualizing insights with Matplotlib, or leveraging the performance-oriented polars library, this book provides a comprehensive guide for both beginners and seasoned data scientists. With a blend of theoretical understanding and practical implementation, readers will acquire the skills necessary to tackle real-world data challenges and unlock the vast possibilities within the Python data science ecosystem. By mastering open-source libraries in data science, readers will be able to apply this knowledge to solve real-world problems and work on various useful projects according to their needs.

The first part of the book is dedicated to an in-depth exploration of the NumPy library, laying the groundwork for proficient data manipulation in Python. Readers will explore fundamental concepts such as the creation of NumPy arrays, understanding the distinctions between lists and arrays, and the application of arithmetic operations. The chapter also sheds light on advanced topics like broadcasting and matrix multiplication. With practical examples, this section ensures a comprehensive understanding of NumPy's capabilities, equipping readers with the skills necessary to efficiently handle numerical data for various data science applications. Then, we will unfold the powerful functionalities of both SciPy and Matplotlib, extending the readers' capabilities in the realm of scientific computing and data visualization. The exploration of SciPy introduces concepts like optimizers, sparse data handling, graph algorithms, and integration techniques, enabling readers to tackle a broad spectrum of scientific and engineering challenges. Transitioning seamlessly, Matplotlib is unveiled as a quintessential tool for data visualization, covering an array of plots such as line plots, bar plots, pie charts, histograms, scatter plots, and subplots. Various practical examples in this section will provide a comprehensive understanding of how to effectively communicate complex data through visually compelling plots, setting the stage for advanced data exploration.

In the later part of the book, the focus shifts to pandas, a versatile library for data manipulation and analysis. Readers will master the creation of pandas series and dataframes, along with advanced techniques like filtering, sorting, and aggregation. The exploration extends to the polars library, emphasizing its modern approach to dataframe manipulation and its performance advantages. The chapter on seaborn delves into statistical data visualization, covering essential plots like heatmaps, box plots, and scatter plots. Additionally, readers will discover the capabilities of ChatGPT in conjunction with open libraries of data science. With a rich array of solved examples in this section, readers will acquire a holistic skill set, empowering them to tackle diverse data challenges and innovate in their data science endeavors.

This book is divided into **16 chapters**. Each chapter description is listed as follows:

Chapter 1: Environmental Setup for Using Data Science Libraries in Python - This chapter covers the key aspects of setting up an effective Python programming environment, highlighting the importance of using an **Integrated Development Environment** (**IDE**). It begins with a step-by-step guide to installing Jupyter Notebook on a Windows platform, along with an overview of its functionalities. The focus will then move to installing **Visual Studio Code** (**VSCode**) for Python development and exploring its features for coding. Finally, the chapter introduces essential Python data science libraries, providing a foundation for learners to utilize these powerful tools in their programming journey.

Chapter 2: Exploring Numpy Library for Data Science in Python - This chapter covers a clear understanding of the comparisons between lists and numpy arrays and what they entail. We will see the creation of ndarrays through different methods, including utilizing list and tuple data structures. We will also demonstrate various functions using Python code snippets and peep into ndarray creation with random values using a module. The distinction between view and copy in numpy will be explained using examples that are crucial for memory efficiency. We will learn different methods to access individual elements or subsets of elements in ndarrays. We will explore how to iterate over elements of ndarrays using loops and explore various arithmetic operators available in numpy. In the end, we will learn how to use broadcasting to perform operations on ndarrays with different shapes.

Chapter 3: Exploring Array Manipulations in Numpy - This chapter covers an idea about various array manipulation functions and variables available in numpy. We will understand different methods for joining ndarrays and explore how to split ndarrays into smaller ones. Sorting of ndarrays in numpy will also be discussed. Some of the search functions available in numpy will be explored along with the insertion and deletion of elements into/from ndarrays will be carried out. The usage of the dot function in numpy for matrix multiplication will be explored. Finally, the linalg module in numpy for linear algebra will be well understood with various examples.

Chapter 4: Exploring Scipy Library for Data Science in Python - This chapter will cover the basic difference between numpy and scipy array. The aim is to explore the scipy constants which represent physical quantities, mathematical, scientific, and other useful values. We will also discuss the optimizers in scipy where different optimization algorithms available will be discussed with some examples, like finding the roots of an equation and many more. Additionally, we will study sparse data and sparse matrix representation in scipy, enabling efficient storage and manipulation of large, mostly empty matrices. Different sparse matrix types in scipy will be well explored. We will learn about graphs in scipy where the module provides several functions to effectively analyze and work with sparse graphs. The chapter covers integration techniques in scipy which are useful for numerical integration of functions. In the end, we will discuss the interpolation methods in scipy which enables the estimation of values between known data points.

Chapter 5: Line Plot exploration with Matplotlib Library - This chapter covers Python's data visualization tools along with a wide array of techniques and concepts to enhance our ability to represent and analyze data effectively. First to learn will be line plots where we will explore the creation of line plots by passing two ndarrays, adding essential elements like titles, x-labels, and y-labels, and advancing our skills with properties like linestyle, color, alpha, linewidth, markersize, markerfacecolor, and figure size customization. We will also learn how to plot multiple lines in a single plot, creating line plots with single ndarrays, incorporate grid lines (both major and minor), and effectively utilize legends, xlim, and ylim functions.

Chapter 6: Charting Dta with Various Visuals Using Matplotlib - This chapter covers the bar plots where various aspects such as changing the color, width, bottom position, left alignment and right alignment of individual bars, as well as adding labels to bars will be learned. We will also venture into Horizontal Bar Charts, Stacked Bar Charts (both vertical and horizontal), and Grouped Bar Charts, providing us with a comprehensive understanding of bar chart variations. Additionally, we will master the art of creating i.e. Charts, Histograms, Scatter Plots, and subplots in Matplotlib, equipping us with a versatile toolkit for data visualization and analysis in Python.

Chapter 7: Exploring Pandas Series for Data Science in Python - This chapter covers a comprehensive range of topics related to pandas series and dataframes in Python, equipping them with the skills and knowledge needed for effective data manipulation and analysis. We will start by exploring pandas series, covering fundamental aspects such as series creation, data access, slicing, and filtering. We will also discuss more advanced topics like using callable objects for selection, leveraging useful attributes, applying functions with the ‘apply’ method, aggregating data, and performing basic arithmetic operations. The chapter will further emphasize series transformations and iteration for a well-rounded understanding.

Chapter 8: Exploring Pandas Dataframe for Data Science in Python - This chapter covers the pandas dataframes, readers will gain insights into dataframe construction and exclusive methods and attributes applicable only to dataframes. We will address the critical task of handling missing data, arithmetic operations for dataframes, and the addition of new columns. The usage of the ‘fillna’ method for handling missing values will also be covered. Sorting, ranking, and filtering data within dataframes will be thoroughly explored along with techniques for checking data inclusion, identifying missing values, and handling duplicates.

Chapter 9: Advanced Dataframe Filtering Techniques - This chapter covers various methods for renaming index labels and column names, as well as efficient ways to delete rows and columns from dataframes. It will introduce the powerful ‘query’ method for data filtering and explore additional advanced techniques such as using ‘apply’ to manipulate dataframe data and finding the largest and smallest values with ‘nlargest’ and ‘nsmallest.’ Text data handling within pandas will be addressed, demonstrating how to filter dataframe rows with string methods. Practical examples of data modification in dataframes will provide readers with hands-on experience in real-world data manipulation.

Chapter 10: Exploring Polars Library for Data Science in Python - This chapter covers a comprehensive exploration of the polars data manipulation library in Python. First, we will highlight the key differences between pandas and polars, shedding light on the unique advantages and features that polars bring to the table. Then, we will explore polars data types, categorizing them into Numeric, Nested, Temporal, and Others Groups, providing a solid understanding of the data structures. Readers will then venture into the heart of polars, gaining insights into its data structures, including series and dataframe, and learning how to work with them effectively. Next, we will unveil the concept of contexts in polars, focusing on essential operations, selection, and filtering techniques. The groupby concept is demystified, enabling readers to harness the power of polars for data aggregation and summarization. The concept of a Lazy API will be well elucidated, demonstrating how it enhances performance and resource utilization.

Chapter 11: Exploring Expressions in Polars - This chapter will cover the subtleties of expressions in polars along with basic operators, column selections, functions, casting, string operations, aggregation, handling missing data, and leveraging folds, lists, and arrays. We will also introduce the integration of numpy in polars, offering a bridge between these two powerful libraries. Finally, readers will gain a deep understanding of when different operations will be performed with polars and pandas, thus helping to make informed choices when working with data in Python.

Chapter 12: Exploring Seaborn Library for Data Science in Python - This chapter covers the concept of some basic statistical terms, such as quantitative and qualitative variables, mean, and their significance in data analysis. They will understand the distinction between variables that represent numerical measurements (quantitative) and those that represent categories or labels (qualitative). The reader will also be familiar with various built-in datasets available in seaborn, gaining practical exposure to real-world datasets for data visualization and analysis. Furthermore, the reader will comprehend the principles of plot styling in seaborn, learning how to customize the aesthetics of plots for better presentation and interpretation. The concept of color palettes in seaborn, including qualitative, sequential, and diverging palettes, will be covered, enabling the reader to choose appropriate color schemes for different types of data and visualizations.

Chapter 13: Crafting Seaborn Plots: KDE, Line, Violin, and Facets - This chapter covers the skills to create various advanced plots in seaborn, such as heatmap plots for visualizing matrices of data, KDE plots for exploring the distribution of a single variable, violin plots for combining aspects of box plots and KDE plots, line plots for depicting trends, scatter plots for visualizing the relationship between two variables, joint plots for combining different types of plots in a single grid, and FacetGrid for creating grids of subplots based on categorical variables.

Chapter 14: Integrating Data Science Libraries with ChatGPT Prompts - This chapter covers the topics to illuminate readers on the versatile applications of ChatGPT in the exploration of open-source data science libraries. Firstly, it aims to guide users in formulating effective prompts for ChatGPT, tailored to each library, including Numpy, Scipy, Matplotlib, Pandas, Polars, and Seaborn to extract valuable insights and coding solutions. We will cover various topics, including leveraging ChatGPT for generating insightful prompts and queries to explore data science libraries, seeking assistance for Python code utilizing these libraries, collaboratively generating comprehensive cheat sheets, and addressing challenges faced by novice users.

Chapter 15: Exploring Automated EDA Libraries for Machine Learning - This chapter will introduce learners to a diverse array of Python libraries tailored for data visualization and analysis, each uniquely contributing to an enriched data exploration experience. Beginning with the PyGWalker Visual library, readers will discover how to seamlessly integrate it with datasets to create visually appealing representations. The exploration continues with the dataprep library, offering insights into efficient data preparation and analysis. Subsequently, learners will explore the capabilities of the autoviz and pandas_visual_analysis, libraries, each providing distinct functionalities and visualization approaches to enhance the understanding and interpretation of datasets.

Chapter 16: Case Studies Using Data Science Libraries - This chapter covers a practical application of data science methodologies by exploring two distinct datasets. The first case study shifts attention to an Electrical Fault Classification dataset. This dataset is designed to help identify and categorize various types of electrical faults in power systems. This dataset typically includes features such as voltage, current, and other relevant electrical parameters collected over time or during specific fault events. By analyzing these features, we will explore no-fault and different fault conditions. Libraries like Pandas and numpy will be used for data manipulation and preprocessing. Visualization libraries such as Matplotlib and Seaborn help in understanding the data distribution and model performance. The second case study focuses on the Titanic dataset, utilizing a range of data science libraries. Learners will employ popular Python libraries such as pandas, numpy and seaborn to preprocess and visualize the data, gaining insights into factors influencing passenger survival and various other factors focusing on the null values.

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CHAPTER 1

Environmental Setup for Using Data Science Libraries in Python

Introduction

In this chapter, we will explore the data science library in Python. However, before learning about various data science libraries, it is quite important to create an environmental setup for installing and using these data science libraries in Python. Setting up the environment for utilizing data science libraries like NumPy, SciPy, Matplotlib, Pandas, and others in Python ensures effective data analysis and modeling workflows. This entails managing dependencies, version control, and package management to guarantee project compatibility and reproducibility. By creating isolated environments, potential conflicts between different library versions are mitigated, facilitating seamless collaboration and reproducibility of results. So, let us get into the intricate details of Python installation and **Integrated Development Environments** (**IDE**s) like VSCode and Jupyter Notebook for writing and executing the Python code.

Structure

In this chapter, we will discuss the following topics:

- Introduction to Python
- Setup Installation in Windows for Jupyter Notebook
- Insights of Jupyter Notebook

- Demo program using Jupyter Notebook
- Introduction to Data Science Libraries in Python

Objectives

This chapter will discuss the essential aspects of setting up a conducive programming environment for Python, emphasizing the significance of an IDE. The discussion commences with the installation process for the Jupyter Notebook on a Windows platform, guiding learners through the setup and providing insights into its functionality. Subsequently, the focus shifts to installing **Visual Studio Code** (**VSCode**) for Python development, exploring its usage for code development. The chapter will conclude with an introduction to fundamental data science libraries in Python, laying the groundwork for learners to leverage these powerful tools in their programming journey.

Introduction to Python

Before we explore this topic, it is essential to set up our development environment. In this chapter, we will guide you through installing Python on your system, ensuring you have everything you need to start writing and executing Python code. Python is an open-source, high-level programming language renowned for its simplicity, readability, and extensive support for various programming paradigms. Whether you are a beginner taking your first steps into programming or an experienced developer seeking a powerful tool for web development, data analysis, machine learning, or scientific computing, Python has something to offer. To begin harnessing the power of Python, the first step is to install the Python interpreter on your computer. The Python interpreter is the core component that executes Python code and provides access to the vast array of libraries and tools available in the Python ecosystem. In this chapter, we will walk you through the installation process for Python on Windows operating systems, including *Windows*, *macOS,* or *Linux OS*.

The steps for installing Python on Windows are mentioned below:

1. Visit the Python website: **https://www.python.org/downloads/** to download the latest version of Python. Here, we have downloaded the latest Python version 3.12.2.
2. We use 64-bit Windows OS and will click or execute the Python installer file.
3. The following window will pop out, and the user can choose **Install Now** or **Customize** installation. Here, we will be selecting the **Install Now** option. Also, remember initially, there are two unchecked checkboxes which are:
    a. Use admin privileges when installing `py.exe`.
    b. Add `python.exe` to `PATH`.
4. Use admin privileges when installing `py.exe`. This option grants the Python installer administrative privileges during installation. It is essential for installing

Python in system-wide directories or when installing packages that demand elevated permissions. Enabling this ensures a smooth installation process without encountering permission-related issues. This option can also be used to change the Python installation folder.

5. Add **`python.exe`** to **`PATH`**. By selecting this option, the Python installer adds the directory containing **`python.exe`** to the **`PATH`** environment variable. This inclusion allows easy access to Python commands from any command prompt or terminal window without specifying the full path to the Python executable. It streamlines the usage of Python across the system, enhancing convenience for running Python scripts and commands.

The steps for installing Python on macOS are mentioned below:

1. **Visit the Python website**: Go to **https://www.python.org/downloads/** to download the latest version of Python for macOS.
2. **Run the installer**: Open the downloaded **`.pkg`** file and follow the instructions in the installation wizard.
3. **Verify the installation**: Open a terminal and type **`python3 --version`** to confirm that Python has been installed correctly.

The steps for installing Python on Linux are mentioned below:

1. **Use the package manager**: Most Linux distributions come with Python pre-installed. However, if you need to install or upgrade Python, you can use the package manager. For example, on Ubuntu, you can use the following commands:

   ```
   sudo apt update
   ```

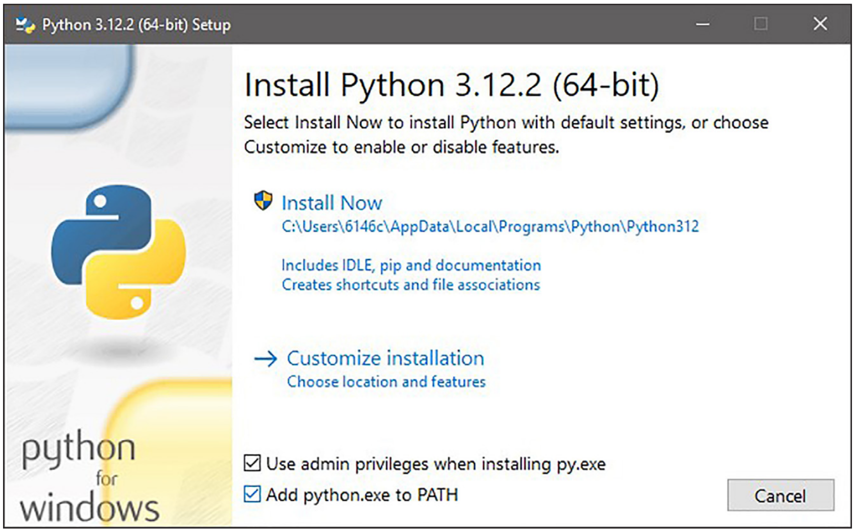
   ```
   sudo apt install python3
   ```

2. **Verify the installation**: Open a terminal and type **`python3 --version`** to confirm that Python has been installed correctly.

We have used Python version 3.11.4 in this book, which means the micro release of Python 3.11 may contain bug fixes and minor enhancements compared to earlier micro releases within the Python 3.11 series. But to show you all the installation steps, we will be showing you Python version 3.12.2, which is the latest version as of 6 February 2024. By the end of this chapter, readers will have a fully functional Python environment set up on their system, ready to embark on their programming journey. Whether you are a student, professional, or hobbyist, Python offers a welcoming and intuitive platform for turning your ideas into reality.

This revision includes installation instructions for Windows, macOS, and Linux users, ensuring that the content is comprehensive and helpful for all readers.

In most cases, it is recommended that you leave these checkboxes checked to ensure a smooth installation experience and convenient Python usage on your system. Refer to the following figure for a better understanding:



Install Python 3.12.2 (64-bit)

Select Install Now to install Python with default settings, or choose Customize to enable or disable features.

Install Now
C:\Users\6146c\AppData\Local\Programs\Python\Python312

Includes IDLE, pip and documentation
Creates shortcuts and file associations

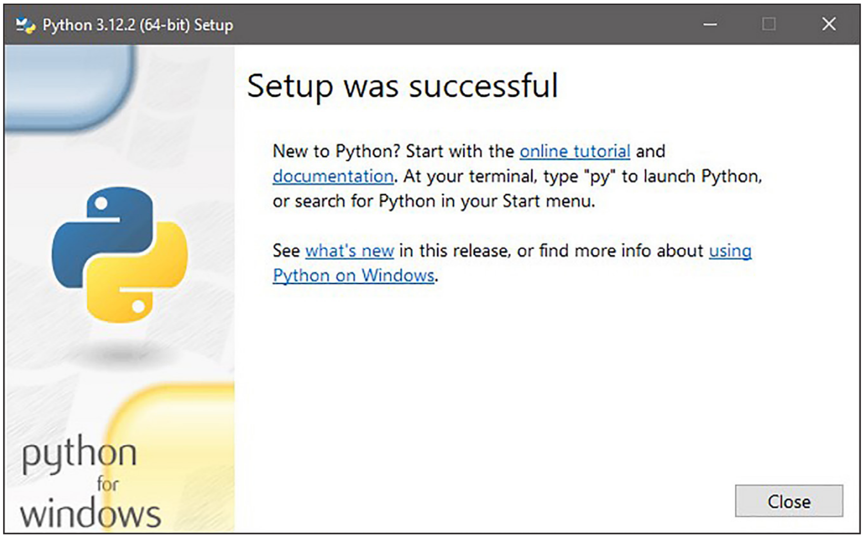
→ Customize installation
Choose location and features

☑ Use admin privileges when installing py.exe
☑ Add python.exe to PATH

Figure 1.1: Python installation on running the Python executable

Refer to the following steps for a better understanding:

1. We will be selecting the **Install Now** option as a recommended option where the default installation path will be **`C:\Users\[user]\AppData\Local\Programs\Python\Python[version]`** for the existing user, which will include the IDLE, pip, and documentation and thus create shortcuts and file associations as mentioned in *Figure 1.1*.
2. Once the installation has been done, the following image will pop out, as displayed in *Figure 1.2*, where the user can close the image.



Setup was successful

New to Python? Start with the online tutorial and documentation. At your terminal, type "py" to launch Python, or search for Python in your Start menu.

See what's new in this release, or find more info about using Python on Windows.

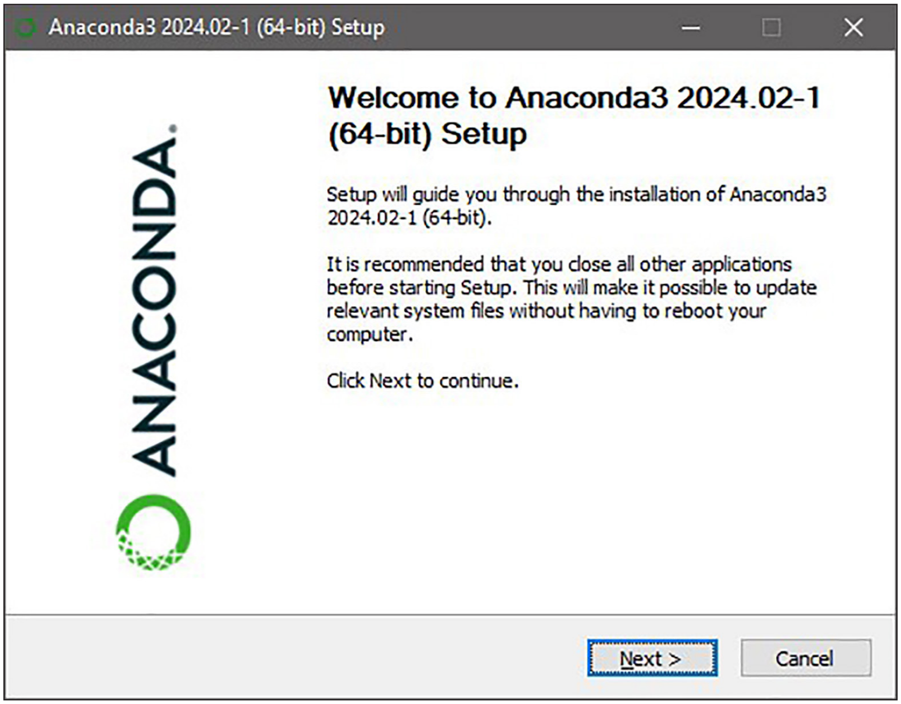
Figure 1.2: Image depicting the successful installation of Python version

Once Python is successfully installed, the user can view the Python version using IDLE (Python 3.12 64-bit), which is installed and can be searched in Windows apps. Python's built-in IDE will be opened when IDLE is run. Another way is that the user can navigate to the directory where Python is installed on the system and double-click `python.exe`.

Setup installation in Windows for Jupyter Notebook

Now, we shall view the steps of installing Anaconda on Windows OS:

1. First, we will download the Anaconda installer by visiting the website **https://www.anaconda.com/download**. Here, we have downloaded Anaconda3 2024.02-1.
2. Once downloaded, we will run this installer file, and we are just getting started with the pop-up of the following image file, as shown in *Figure 1.3*:



Welcome to Anaconda3 2024.02-1 (64-bit) Setup

Setup will guide you through the installation of Anaconda3 2024.02-1 (64-bit).

It is recommended that you close all other applications before starting Setup. This will make it possible to update relevant system files without having to reboot your computer.

Click Next to continue.

Figure 1.3: *Image depicting Step-1 of getting started of Anaconda3*

3. On clicking the **Next** button of *Figure 1.3*, read the **License Agreement** as shown in *Figure 1.4:*