Preface

Large language models (LLMs) have had a profound and far-reaching impact on the world. By enabling machines to better understand and generate human-like language, LLMs have opened new possibilities in the field of AI and impacted entire industries.

This book provides a comprehensive and highly visual introduction to the world of LLMs, covering both the conceptual foundations and practical applications. From word representations that preceded deep learning to the cutting-edge (at the time of this writing) Transformer architecture, we will explore the history and evolution of LLMs. We delve into the inner workings of LLMs, exploring their architectures, training methods, and fine-tuning techniques. We also examine various applications of LLMs in text classification, clustering, topic modeling, chatbots, search engines, and more.

With its unique blend of intuition-building, applications, and illustrative style, we hope that this book provides the ideal foundation for those looking to explore the exciting world of LLMs. Whether you are a beginner or an expert, we invite you to join us on this journey to start building with LLMs.

An Intuition-First Philosophy

The main goal of this book is to provide an *intuition* into the field of LLMs. The pace of development in the Language AI field is incredibly fast and frustration can build trying to keep up with the latest technologies. Instead, we focus on the fundamentals of LLMs and intend to provide a fun and easy learning process.

To achieve this *intuition-first philosophy* we liberally make use of visual language. Illustrations will help give a visual identity to major concepts and processes involved in the learning process of LLMs.[1] With our illustrative method of storytelling, we want to take you on a journey to this exciting and potentially world-changing field.

Throughout the book, we make a clear distinction between representation and generative language models. Representation models are LLMs that do not generate text but are commonly used for task-specific use cases, like classification, whereas generation models are LLMs that generate text, like GPT models. Although generative models are typically the first thing that comes to mind when thinking about LLMs, there is still much use for representation models. We are also loosely using the word "large" in *large language models* and often elect to simply call them language models as size descriptions are often rather arbitrary and not always indicative of capability.

Prerequisites

This book assumes that you have some experience programming in Python and are familiar with the fundamentals of machine learning. The focus will be on building a strong intuition rather than deriving mathematical equations. As such, illustrations combined with hands-on examples will drive the examples and learning through this book. This book assumes no prior knowledge of popular deep learning frameworks such as PyTorch or TensorFlow nor any prior knowledge of generative modeling.

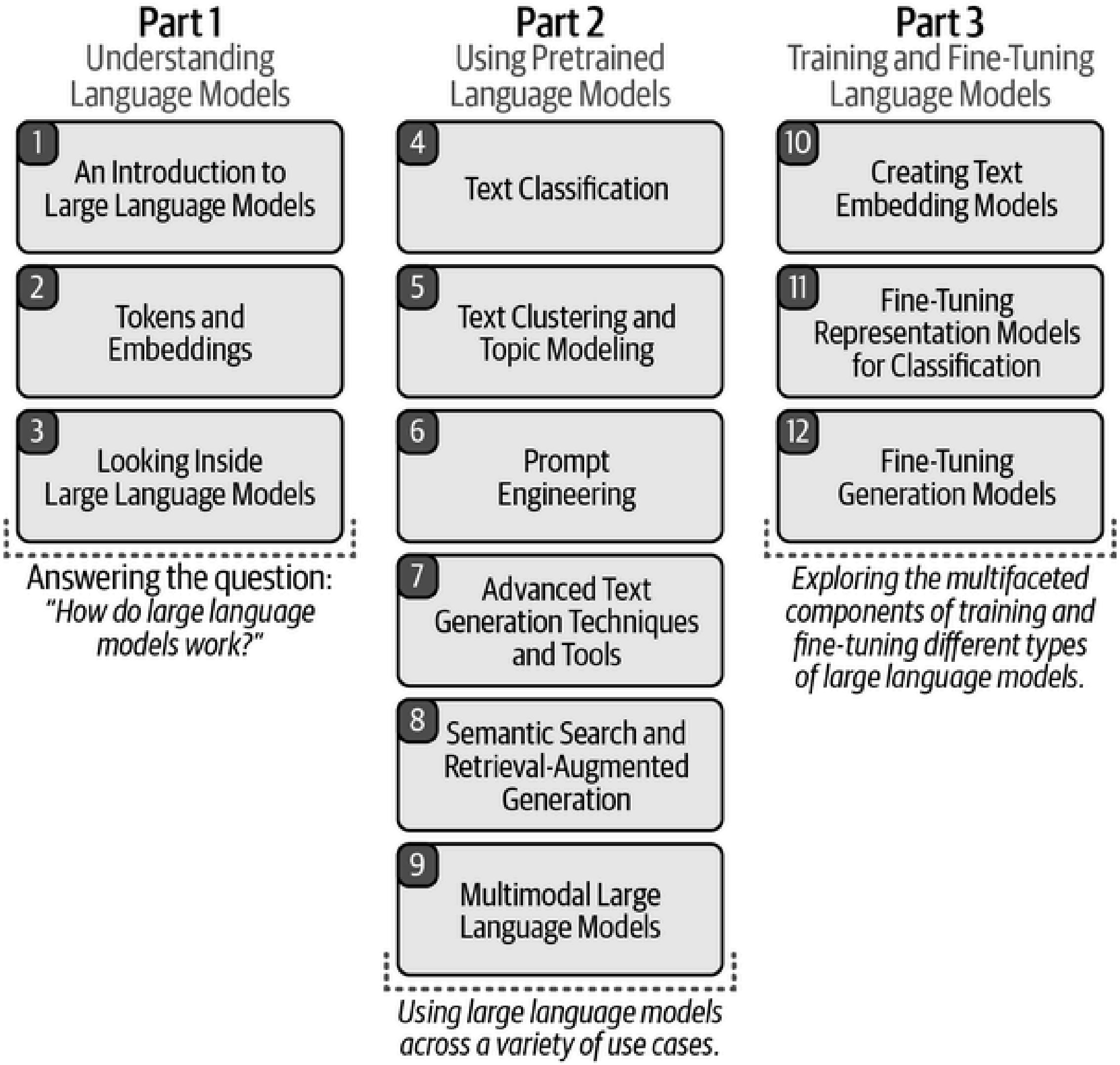
If you are not familiar with Python, a great place to start is Learn Python, where you will find many tutorials on the basics of the language. To further ease the learning process, we made all the code available on Google Colab, a platform where you can run all of the code without the need to install anything locally.

Book Structure

The book is broadly divided into three parts. They are illustrated in Figure P-1 to give you a full view of the book. Note that each chapter can be read independently, so feel free to skim chapters you are already familiar with.

Part I: Understanding Language Models

In Part I of the book, we explore the inner workings of language models both small and large. We start with an overview of the field and common techniques (see Chapter 1) before moving over to two central components of these models, tokenization and embeddings (see Chapter 2). We finish this part of the book with an updated and expanded version of Jay's well-known Illustrated Transformer, which dives into the architecture of these models (see Chapter 3). Many terms and definitions will be introduced that are used throughout the book.



Part 1
Understanding Language Models
1 An Introduction to Large Language Models
2 Tokens and Embeddings
3 Looking Inside Large Language Models
Answering the question: "How do large language models work?"
Part 2
Using Pretrained Language Models
4 Text Classification
5 Text Clustering and Topic Modeling
6 Prompt Engineering
7 Advanced Text Generation Techniques and Tools
8 Semantic Search and Retrieval-Augmented Generation
9 Multimodal Large Language Models
Using large language models across a variety of use cases.
Part 3
Training and Fine-Tuning Language Models
10 Creating Text Embedding Models
11 Fine-Tuning Representation Models for Classification
12 Fine-Tuning Generation Models
Exploring the multifaceted components of training and fine-tuning different types of large language models.

Figure P-1. All parts and chapters of the book.

Part II: Using Pretrained Language Models

In Part II of the book, we explore how LLMs can be used through common use cases. We use pretrained models and demonstrate their capabilities without the need to fine-tune them.

You learn how to use language models for supervised classification (see Chapter 4), text clustering and topic modeling (see Chapter 5), leveraging embedding models for semantic search (see Chapter 6), generating text (see Chapters 7 and 8), and extending the capabilities of text generation to the visual domain (see Chapter 9).

Learning these individual language model capabilities will equip you with the skill set to problem-solve with LLMs and build more and more advanced systems and pipelines.

Part III: Training and Fine-Tuning Language Models

In Part III of the book, we explore advanced concepts through training and fine-tuning all kinds of language models. We will explore how to create and fine-tune an embedding model (see Chapter 10), review how to fine-tune BERT for classification (see Chapter 11), and end the book with several methods for fine-tuning generation models (see Chapter 12).

Hardware and Software Requirements

Running generative models is generally a compute-intensive task that requires a computer with a strong GPU. Since those are not available to every reader, all examples in this book are made to run using an online platform, namely Google Colaboratory, often shortened to “Google Colab.” At the time of writing, this platform allows you to use an NVIDIA GPU (T4) for free to run your code. This GPU has 16 GB of VRAM (which is the memory of your GPU), which is the minimum amount of VRAM we expect for the examples throughout the book.

NOTE

Not all chapters require a minimum of 16 GB VRAM as some examples, like training and fine-tuning, are more compute-intensive than others, such as prompt engineering. In the repository, you will find the minimum GPU requirements for each chapter.

All code, requirements, and additional tutorials are available in this book’s repository. If you want to run the examples locally, we recommend access to an NVIDIA GPU with a minimum of 16 GB of VRAM. For a local installation, for example with conda, you can follow this setup to create your environment:

```
conda create -n thellmbook python=3.10
conda activate thellmbook
```

You can install all the necessary dependencies by forking or cloning the repository and then running the following in your newly created Python 3.10 environment:

```
pip install -r requirements.txt
```

API Keys

We use both open source and proprietary models throughout the examples to demonstrate the advantages and disadvantages of both. For the proprietary models, using OpenAI and Cohere's offering, you will need to create a free account:

OpenAI

> Click "sign up" on the site to create a free account. This account allows you to create an API key, which can be used to access GPT-3.5. Then, go to "API keys" to create a secret key.

Cohere

> Register a free account on the website. Then, go to "API keys" to create a secret key.

Note that with both accounts, rate limits apply and that these free API keys only allow for a limited number of calls per minute. Throughout all examples, we have taken that into account and provided local alternatives if necessary.

For the open source models, you do not need to create an account with the exception of the Llama 2 model in Chapter 2. To use that model, you will need a Hugging Face account:

Hugging Face

> Click "sign up" on the Hugging Face website to create a free account. Then, in "Settings" go to "Access Tokens" to create a token

that you can use to download certain LLMs.

Conventions Used in This Book

The following typographical conventions are used in this book:

Italic

Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`

Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

`Constant width bold`

Shows commands or other text that should be typed literally by the user.

`Constant width italic`

Shows text that should be replaced with user-supplied values or by values determined by context.

TIP

This element signifies a tip or suggestion.

NOTE

This element signifies a general note.

Using Code Examples

Supplemental material (code examples, exercises, etc.) is available for download at *https://github.com/HandsOnLLM/Hands-On-Large-Language-Models*.

If you have a technical question or a problem using the code examples, please send email to *support@oreilly.com*.

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Acknowledgments

Writing this book has been an incredible experience, collaboration, and journey for us.

The field of (large) language models is one of the most dynamic areas in technology today, and within the span of writing this book, we have witnessed extraordinary advancements. Yet, despite the rapid pace of change, the fundamental principles remain strikingly consistent which made the writing process particularly intriguing. We are grateful to have had the opportunity to explore this field in-depth at such a pivotal moment.

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[1] J. Alammar. "Machine learning research communication via illustrated and interactive web articles." *Beyond Static Papers: Rethinking How We Share Scientific Understanding in ML*. ICLR 2021 Workshop (2021).