Prompt Engineering

Hands-on guide to prompt engineering for AI interactions

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Dedicated to

*To my mother, **Joanne**, who encouraged me to read*
*my wife, **Stacie**, who encouraged me to write*
*my daughters, **Katie** and **Maddie**, who encourage me to dream*

About the Author

Eric C. Richardson has 30 years of experience in technology. He was first exposed to an early home computer, the Altair 8800, when he was in primary school when his father built one. He never stopped working with computers and technology. He is currently focusing on artificial intelligence, security architecture, and technology governance, risk, and compliance. He spent 17 years at Microsoft Security in their digital supply chain in a variety of roles. He has been a CISO of startups and various senior leadership roles in other companies but has always focusing on integrity and security.

Eric has also been a volunteer teacher in high school for AP computer science and has taught college-level courses. He has published multiple books and articles on technology and the internet since the mid 1990's. He holds an undergraduate degree in Management Information Systems, a Master's in Computer Science with an emphasis on cybersecurity engineering, and a Master's degree in Business Administration with a focus on technology management. Eric is a passionate supporter of STEM education and Neurodiversity support in tech. He has been married for thirty years to his amazing wife, Stacie, and has two daughters: Katherine and Madelyn. He is an experienced technology consultant who enjoys the process of partnering with an organization to move towards a stronger future empowered by technology.

About the Reviewers

- **Maxim Salnikov** is a tech and cloud community leader based in Oslo. With over two decades of experience as a web developer, he shares his deep expertise in web platforms, cloud computing, and AI by speaking at and delivering training sessions at developer events worldwide.

  By day, Maxim drives cloud and AI solution development across European companies as the go-to-market leader of Microsoft's application innovation and developer productivity businesses.

  In his spare time, he organizes events for Norway's largest web and cloud development communities and advises startups on AI technology and strategy as a board member.

  Maxim is passionate about exploring and experimenting with generative AI, including AI-assisted development and autonomous AI agents. To foster global discussions and connect with like-minded professionals, he founded and organized the Prompt Engineering Conference—the first of its kind on a global scale.

- **Dr. Michael Seller** is an AI strategist, prompt engineering expert, and business consultant specializing in AI-driven solutions. He holds a Doctorate in Business Administration and certifications in AI and data analytics. As the founder of AI Alchemy, he has developed over 200 tailored prompts across various domains, helping businesses and nonprofits optimize their operations. Dr. Seller has conducted AI training workshops for organizations such as the Humanity House Foundation, the Center of Public Safety for Women, and Ampac, equipping professionals with practical AI skills. His work spans academia, consulting, and technical reviewing for AI publications.

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Preface

Forty years ago the world thought artificial intelligence was just around the corner. In the last several years, we are finally seeing AI begin to fit the potential we all thought it could. This book acts as a resource for individuals who wish to master complex methods that influence our engagement with AI systems. Developers, researchers, and enthusiasts alike will find that the insights presented here work to improve your knowledge and abilities in constructing effective AI prompts. The book opens with a fundamental introduction to machine learning (ML) and artificial intelligence (AI) while exploring their fundamental principles. Beginning with AI philosophical foundations pioneered by Alan Turing and progressing through machine learning paradigms like supervised and unsupervised learning, the book establishes essential knowledge to grasp complex interactive developments. Exploration of prompt engineering specifics reveals how transformer-based models act as transformative elements critical for contemporary AI applications. Exploring the functions of generative models such as GANs and transformers helps readers understand the advanced architecture that drives current AI systems. The subsequent chapters examine practical prompt engineering methods. This section teaches how to build and refine prompts that create improved interactions with AI systems. The discussion encompasses practical applications of AI, ethical challenges, and societal impacts to deliver a comprehensive analysis of prompt engineering consequences. Ultimately, this book aims to deliver educational value along with inspirational insights. This work provides guidance to help you face AI challenges and opportunities through innovative, ethical applications of your learning. This book serves as an indispensable guide for your prompt engineering skills development regardless of if you work on refining chatbots or creating sophisticated AI systems.

Chapter summaries:

Chapter 1: A Brief Overview of ML and AI - This chapter offers a succinct introduction to the domains of ML and AI. It starts by explaining basic definitions and foundational concepts, preparing the readers to comprehend the wider applications of these technological fields. This chapter details the development of machine learning throughout and divides machine learning into distinct categories based on the different methods used to process data for model training. The chapter examines emerging learning paradigms while showcasing their distinctive methods and impacts on the field. The chapter provides new ML and AI learners with a straightforward, structured introduction that highlights the field's diverse and dynamic transformative technologies.

Chapter 2: Evolution of Machine Learning - This chapter examines the evolution ML by exploring its beginnings with symbolic AI and following its development into today's statistical learning techniques. The discussion initiates by examining early machine learning methodologies. We also cover significant historical achievements in neural network research and the backpropagation algorithm's importance since its introduction in 1986. We explore how support vector machines (SVMs) gained prominence during the 1990s and their significant influence on machine learning. The chapter examines how big data, together with advanced computational abilities enabled by hardware innovations such as GPUs and TPUs played a transformative role. The rise of deep learning is also introduced.

Chapter 3: Development of Generative Models - This chapter examines how generative models evolved into an essential part of artificial intelligence. The chapter starts by explaining generative models and demonstrating how they differ from discriminative models through their capability to synthesize new data samples. We examine the development of generative models by understanding their historical evolution. Our exploration covers the functioning of GANs by examining generator and discriminator networks as well as demonstrating their wide-ranging uses in image synthesis and text generation beyond these areas. The concluding section of the chapter prepares readers for the emergence of transformers by suggesting their future transformative influence on generative AI.

Chapter 4: Rise of GPT and Transformer-Based Models - This chapter explores how GPT models and Transformer architectures emerged and shaped AI development. It provides an account of how transformer-based models developed and became crucial in AI through their application in prompt engineering. The chapter starts by tracing machine learning model development before introducing the revolutionary emergence of transformer-based architectures. We examine the self-attention mechanism and look into major models, including BERT and GPT. The chapter covers fundamental elements of Transformer architecture, including scaled dot-product attention and multi-head attention alongside position-wise feed-forward networks and positional encoding. We also cover the benefits of the self-attention mechanism and combine a comprehensive description of AI technology developments with discussions on how these models advance prompt engineering capabilities while serving as essential reading material for those seeking knowledge about emerging AI technologies.

Chapter 5: Transformer-based Models in Prompt Engineering - This chapter explores the essential function of transformer-based models as they apply to prompt engineering. The chapter presents successful case studies demonstrating real-world instances where transformer-based models have enhanced AI solutions through improved efficiency and effectiveness. We examine transformer models by contrasting them with classic prompt engineering models, including LSTM and GRU networks. The comparative analysis shows that transformer models excel at managing extended data sequences and demonstrate superior capabilities in tasks that involve understanding intricate textual dependencies. This chapter delivers a complete survey of transformer-based models' role in prompt engineering while highlighting their revolutionary impact on AI interaction enhancement and development.

Chapter 6: Transformer Architecture Concepts - This chapter delivers an in-depth analysis of transformer architecture progress while focusing on GPT from OpenAI. The chapter starts by explaining the original GPT model's basic architecture before examining the development of GPT-2 and GPT-3. We also look at various uses of these models, starting from natural language processing applications to creative fields, such as writing and art, before looking at practical industry applications like customer service automation. The narrative demonstrates how these models create transformative changes across multiple sectors while offering a detailed view of their potential and technological advancements.

Chapter 7: The Prompt Ecosystem - This chapter provides an insightful examination of prompt engineering which stands as a vital component when working with transformer-based models in AI and ML domains. The section begins with an explanation of prompt engineering and its goals while clarifying how creating effective prompts can improve AI system performance and accuracy. By analyzing practical examples, the chapter demonstrates that effective prompts enhance AI model performance while ineffective prompts result in ambiguous or inaccurate results. The text explores the different elements that form a prompt and explains prompt structures, dividing them into informative, interrogative, and directive categories. The chapter presents active learning to improve prompts through AI feedback and introduces methods for evaluating prompt performance. This chapter examines the entire prompt ecosystem and demonstrates its essential role in AI and ML while delving into the technical aspects and creative process of prompt engineering.

Chapter 8: Prompt Types In-Depth - The chapter thoroughly examines the different categories of prompts with special emphasis on their application in AI and ML domains and categorizes prompts into several types. We examine open-ended and close-ended prompts. The chapter examines multi-modal prompts that merge text with images and additional data formats to assess their flexible and intricate nature. The discussion includes contextual prompts that demonstrate their ability to produce appropriate responses by utilizing existing information. The chapter surveys additional prompt types that are less prevalent yet hold comparable significance while demonstrating how they can be applied across various sectors. The chapter presents essential insights into how various prompts can be effectively applied to improve AI system interactions and result quality.

Chapter 9: Understanding Tokens - This chapter explores the basic concept of tokens in AI by examining their definition and function along with their working mechanisms within AI models such as GPT-4. The section starts by defining tokens and explaining their crucial role in constructing inputs for machine learning systems to process and generate responses. We examine the tokenization process and demonstrate its complexity and flexibility through examples from different languages. The chapter investigates how token limitations work in AI models and how token limitations affect the structuring of prompts and the general performance of AI systems. This chapter delivers comprehensive insights into token operations and their limitations.

Chapter 10: Efficiency in Prompt Engineering - The chapter thoroughly examines why creating efficient prompts is essential for AI and ML applications. We start by demonstrating the essential role of efficiency in prompt engineering alongside significant advantages that well-designed prompts deliver through enhanced response precision and better system performance. We move forward to examine different methods for creating efficient prompts. The chapter outlines techniques for both evaluating prompt performance and making improvements to their efficiency. The content presents evaluation tools and metrics for prompt assessment and demonstrates the differences between optimized and non-optimized prompts through comparative examples. The chapter intends to provide readers with essential knowledge and tools through which they can improve their prompt engineering skills to boost AI application performance.

Chapter 11: Critical Role of Syntax - This chapter gives a detailed account of how syntax can affect the efficiency of prompts in AI systems. We look at typical syntactical errors while providing guidance on how to prevent making those mistakes. This chapter presents a conversational model along with language techniques that enable actors to maximize that model's effectiveness. The latter portion of the chapter examines advanced techniques in syntax construction.

Chapter 12: Techniques and Strategies for Prompt Engineering - This chapter delivers a comprehensive guide to developing effective AI system prompts. We begin by presenting best practices in prompt crafting. The chapter proceeds to examine advanced prompt engineering techniques and how few-shot learning and zero-shot learning techniques enable AI models to process prompts without needing extensive previous examples. We also cover prompt tuning and optimization methods to enhance prompt effectiveness for specific needs and explain how to manage multi-turn conversations, which are essential for developing more interactive AI exchanges. The chapter demonstrates practical applications by showing real-world examples of these techniques in operation. The content offers case studies and lessons learned from successful implementations.

Chapter 13: Challenges of Quality Prompts - This chapter examines the challenges faced when creating effective prompts to operate AI systems. The initial section identifies fundamental elements that define high-quality prompts, which consist of clear instructions, specific details, and relevant context, along with suitable tone and style. The chapter advances by examining typical obstacles that arise within the field of prompt engineering. We examine how ambiguous prompts produce unexpected or off-topic responses in AI systems and prompt design bias. We learn about the barriers to effective, prompt design while demonstrating the consequences of these challenges.

Chapter 14: Tools and Platforms for Prompt Engineering - This chapter is a critical resource for understanding the different tools essential for creating high-quality AI application prompts. We start by presenting an overview of widely-used platforms such as GPT-3 Playground, Hugging Face Transformers, and the OpenAI API and cover their technical capabilities, user interfaces and distinct features. Subsequently, the chapter provides a practical manual for the effective utilization of these tools and a step-by-step guide for setting up and configuring each platform, along with best practices for crafting and testing prompts as well as methods to analyze and interpret results. The final section of this chapter addresses the integration process of prompt engineering tools into current workflows.

Chapter 15: Ethics in Artificial Intelligence - The chapter examines significant ethical issues that arise throughout the development and application of AI and ML technologies. We start by examining bias and fairness and how AI systems risk reinforcing existing prejudices if not properly managed. The chapter stresses the need to detect and reduce biases to achieve equitable and inclusive results in AI systems. Next, the importance of safeguarding user data and stopping unauthorized access to AI systems becomes the focal point of privacy and security concerns. The text analyzes how technologies such as GPT and other advanced AI systems affect society through job displacement and economic changes, as well as their roles in spreading misinformation and generating deepfakes. The chapter analyzes the regulatory and governance structures to monitor AI development and usage and examines fundamental principles necessary for ethical AI development. We learn the obstacles and essential frameworks for ethical AI implementation and understand how AI technology can advance in a way that supports human rights while being beneficial to society.

Chapter 16: Finances of Prompts and Cost Management - This chapter examines the financial considerations involved in the design and application of prompts within AI systems. We start with an analysis of how various prompt designs affect their processing costs in AI. The discussion transitions to methods that help control and minimize these costs. The chapter explains how AI capabilities help automate repetitive tasks which result in reduced operational costs. The book includes case studies that demonstrate practical applications of cost-efficient prompt engineering in real-world scenarios.

Chapter 17: Future Directions and Challenges of AI and ML - The chapter delivers a forward-looking examination of AI and ML advancements and their ongoing evolution. We examine the recent progress in AI and ML, which concentrates on building new AI models and combining AI with emerging technologies like IoT and quantum computing. The discussion moves forward to explore some upcoming obstacles. The chapter outlines various technical challenges encountered while developing advanced AI technologies that require stronger algorithms and sophisticated management of complex data structures. We learn about the ethical and regulatory dilemmas associated with AI adoption and underscore the necessity for frameworks that promote responsible deployment by tackling privacy, bias, and transparency issues. The chapter investigates future AI applications while emphasizing hybrid models.

Chapter 18: Legal Framework for Artificial Intelligence - This chapter deeply examines legal aspects related to AI creation and distribution of AI-generated content. It starts by providing a comprehensive overview of current legal structures that manage artificial intelligence through national and international regulations. The chapter investigates intellectual property challenges related to AI technologies with a focus on patents and copyrights. We learn about the General Data Protection Regulation (GDPR) along with multiple data protection laws that influence data management practices in AI systems. The security issues organizations encounter while implementing AI technologies are also covered.

Chapter 19: Practical Examples of Chatbots and AI Systems - This chapter delivers an extensive examination of cutting-edge chatbots and AI systems that influence the current conversational AI field. The chapter starts with an examination of leading systems like ChatGPT and ChatGPT Plus while detailing their functions and technological foundations. The text discusses Google's Bard and Gemini by showing what unique features they offer for processing complex questions. We also learn about some practical, real-world examples of prompts that you can implement.

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CHAPTER 1

A Brief Overview of ML and AI

Introduction

It is nearly impossible to read any news today that does not mention **artificial intelligence** (**AI**), **machine learning** (**ML**), or any related areas associated with it. The rapid advancements in AI and ML have created a demand for new skills and knowledge. Prompt engineering is a critical skill for anyone working with AI models, as it directly impacts the quality and reliability of the outputs generated.

Whether you are a seasoned AI practitioner or a newcomer to the field, understanding prompt engineering will enhance your ability to harness the full potential of AI models. By mastering this skill, you can improve the performance of AI systems, create more engaging user experiences, and contribute to the responsible development of AI technologies.

Before we learn about what prompts and, by extension, prompt engineering is, we will need to learn some background information. So, in this chapter, we will introduce some basic foundational elements such as learning AI, ML, and prompt engineering and will touch a bit on the history. By having a solid understanding of how we got here, you will best understand where prompt engineering is going and be ready to unlock the power of prompts, paving the way for a new era of human-AI collaboration.

Structure

This chapter will cover the following topics:

- Key milestones in AI history
- Fundamental concepts of machine learning and artificial intelligence
- Historical context and evolution of AI

Objectives

When you complete this chapter, you will understand the basics of the origin of ML and AI and the historical context in which they arose. You will have an overview of AI and ML from a big-picture perspective. You will understand the basics of the evolution of AI and begin to see the complexity of the area of study. Readers will also understand the various types of AI.

Key milestones in early AI history

Using machines to solve problems is something that defines civilization. The better our machines, the better we can use them. Computers are electronic versions of mechanical computing devices which have existed a very long time, the Middle Ages saw clocks track astronomical events, what they did with gears and rotors was actually create ways to mathematically predict the motion of celestial bodies. These were early mechanical computers effectively. Let us talk about how the descendants of those machines (computers) were used to create a new area of scientific study: AI.

Turing and the concept of a thinking machine

The notion of machines **solving** problems is not new, of course. The roots of what we know of AI today goes back to World War II. A secret group of code breakers was formed at the **Government Code and Cypher School** (**GC&CS**) on the grounds of the British country house *Bletchley Park* in *Buckinghamshire*. It was an amazing team, and one of the best-known among them was *Alan Turing*. Turing was a brilliant mathematician who was recruited as the leader of GC&CS to help use electromechanical devices to break the code of the German electromechanical enciphering device. The German machine is now known as the Enigma machine.

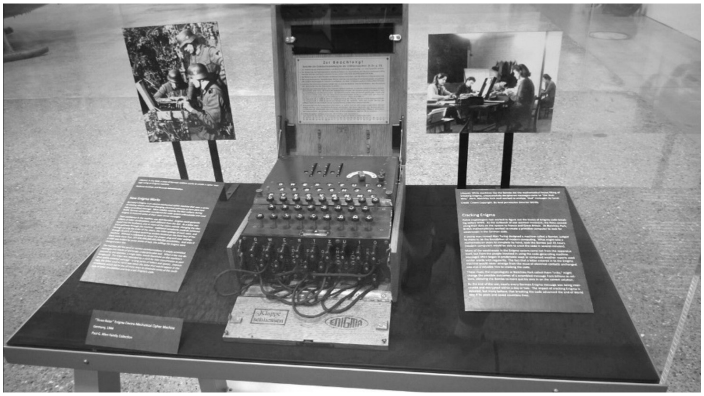

***Figure 1.1**: A photograph of an actual Enigma machine from World War II: From the author's personal collection*

To defeat Enigma the solution was, by our standards, a primitive computer, but quite capable for its time. It was called the **Colossus**, a group of computers used from 1943 to the end of the way. It was the world's first computer in terms of it being a digital programmable platform.

Figure 1.1 shows an actual WWII Enigma machine at the *Flying Heritage & Combat Armor Museum* in *Everett Washington, USA*. The Enigma machine was a device to encrypt and decrypt messages. Simply, it had a keyboard to type and used an electro-mechanical device to encipher the message. Every time you press a key, the machine would change what the next letter could be; if two machines were set up with the right key, one could decrypt another.

To decode a message, the recipient would need an Enigma machine set up like the sender's. They would type in the encoded message, and the machine would reverse the process to reveal the original text.

From a cybersecurity perspective, the Enigma machine represents an early example of a symmetric key encryption system. Both parties need to share a secret (in this case, the rotor settings) to communicate securely. It is also a great example of how mechanical and electrical engineering can be used to create complex cryptographic systems. As someone who has worked in cybersecurity for 25 years, it is quite similar to how cryptography is used today. For example, we would call the agreed-on rotor settings the public key. The rotor settings were changed every day; there was an agreed-on list of settings tied to the date published. Those were amongst the most secret of all documents.

Those secret rotor settings were made up of letters. Although a weakness in the plan was humans preferring a real word as opposed to scrambled letters. Hence, the GC&CS was able to narrow down the possible choice of words that fit the six-character rotor settings.

Using only known six-letter German words, the team using Colossus (then known as the **Bombe**) iterated through every single six-letter word in the day with a simulation of the inner workings of the Enigma machine. As they became successful in this iterative approach, known today as a **brute force attack**, they used this information to help war end faster. Not only was this the first significant example of computers doing calculations faster than humans, but it also eventually gave rise to AI. It was also the first instance of what one could call cyberwarfare since, primarily, cybersecurity today is focused on encryption in one way or another.

The Turing test

After World War II, *Alan Turing* wrote about *Computing Machinery and Intelligence* in an academic paper in 1950. In that paper, he proposed the concept of machine intelligence, which is now known as the Turing test. Rather than providing a direct definition of machine intelligence, Turing suggested an operational approach. He posited that a machine could be considered intelligent if it could engage in a conversation with a human without the human realizing that they were conversing with a machine. This idea is encapsulated in the imitation game, where a machine attempts to mimic human responses well enough to be indistinguishable from a human interlocutor. In some cases, programs that effectively focus chatbots have been able to deceive people into thinking they are conversing with an actual human.

Turing's concept of machine intelligence hinges on the ability of a machine to exhibit behavior indistinguishable from that of a human, particularly in the context of linguistic and conversational tasks. This focus on behavior and performance, rather than internal processes or consciousness, marks a foundational shift in thinking about AI. Turing is one of the individuals who can claim the title of **the father of computer science**, and to this day, the Turing test is taught to computer science students. The question of whether a system analysis can evaluate and then create a judgment and articulate it is at the heart of AI. Others took his efforts and built upon it. The next milestone happened a few years later.

John McCarthy and the Dartmouth conference

The Dartmouth conference, which occurred in 1956, marked the birth of AI and, broadly, computer science as a formal field of study. Early AI programs grew out of this to define the initial approaches to AI problem-solving.

That conference was held at *Dartmouth College* in *New Hampshire* and organized by *John McCarthy, Marvin Minsky, Nathaniel Rochester,* and *Claude Shannon*. It was considered a seminal event in the history of AI. This conference marked the formal birth of AI as a distinct academic discipline. *McCarthy* coined the term AI during this event, setting the stage for decades of research and development. The goal of this conference was to explore the idea that human intelligence could be replicated by machines, laying the groundwork for future AI research. The collaborative environment fostered by this conference brought together prominent researchers who would become pioneers in the field, establishing foundational concepts and stimulating widespread interest in AI. The Dartmouth conference catalyzed significant advancements in computer science, leading to the development of early AI programs and setting a vision that continues to drive the field today.

At that time, outside of science fiction, the notion of machines being able to emulate even rudimentary human intelligence was considered a farcical notion. At the conference, however, they acknowledged that the rapid advancements in computer science and the successful implementation of early computing machines created a fertile ground for such ambitious ideas. Researchers were increasingly interested in exploring the potential of these new machines beyond mere number-crunching. They wondered whether computers could be programmed to perform tasks that required human-like intelligence, such as reasoning, learning, and understanding language.

At that time, *McCarthy* was a young assistant professor who joined *Dartmouth College* a year before. He was particularly captivated by the idea of a computer being able to emulate human intelligence. He envisioned a future where machines could think and solve problems autonomously. To explore this vision, he proposed a summer research project to bring together leading minds in mathematics, engineering, and computer science to discuss and develop the concept of AI.

McCarthy, along with other researchers *Minsky, Rochester, and Shannon*, crafted a proposal that articulated their bold vision to take a few individuals to study the nature of AI for about a year in 1956. Their prominent goal stated that regarding human-equivalent intelligence, *".. a machine can be made to simulate it"* (*McCarthy, John; Minsky, Marvin; Rochester, Nathan; Shannon, Claude (1955)*).

This proposal was groundbreaking in daring to pose that a computer or machine could even resemble a human in terms of abilities. It suggested that human cognitive processes could be understood and replicated by machines, a hypothesis that would drive AI research for decades to come. The conference aimed to explore a variety of topics, including automatic computers, how a machine could be programmed to use a language, neuron nets, and self-improvement, all of which are foundational elements in AI research.

That conference gave us not only the term AI, as we stated, but also defined AI, starting an entirely new area of academic research. It is important to note that computer science degrees had only just begun to be given out a few years before 1953. So, the world had a new area of research created just as the first graduates of an entirely new related field were heading into the workforce.

It was not just computer scientists involved; from the beginning, AI had to be an interdisciplinary field of study. Professionals from mathematics, psychology, engineering, and computer science needed to come together. The notion of ML, **natural language processing** (**NLP**), and symbolic reasoning were evolving together.

Possibly the most important thing that came out of that conference was that it inspired other institutions to begin their own research into AI. To this day this is considered the