Digital Agency: Understand technology and make it work for you

To my family, especially my daughters, Ayesha and Shanti, whose curiosity about technology and productivity inspired me to write this book.

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Preface

"You know, I couldn't do it. I couldn't reduce it to the freshman level. That means we really don't understand it."
Richard Feynman

While putting the finishing touches on my previous book, **A Platform Mindset**, I began to take a step back and think less about the power of digital platforms and more about the power that we hold as individuals and users of these technologies. This power, which exists at both a personal and collective level, is apparent whether looking at AI use today or quantum computing capabilities in the future. Increasingly, the content that we consume about technology is what technology is doing for or to us, as if we are just bystanders. But each and everyone of us, regardless of our technical background or understanding of technology, has human agency in a world of digital agents.

What does that mean? Well, ask your favorite AI or the Wikipedia page about human agency. While there are many definitions, each makes it clear that we humans are autonomous beings, meaning that we act independently and by ourselves. As human agents, don't we owe it to ourselves to become as fluent as possible in the strengths and weaknesses of digital agents? My answer is "yes, absolutely."

I am a computer scientist, but I'm first a human. A human who has daughters, to whom I've dedicated this book, and who wants to build a better world for their and future generations. I care deeply about both technology and people, and as a result, how they intersect and impact one another. That's the first big idea of this book: **human agency,** which is our greatest defense against predatory technology and predatory people who use otherwise technology in a predatory way. Humans should understand technology. Evaluate it. Use it, if it is empowering, and not use it, if it is harmful. I love the definition of machine usefulness (MU) from MIT economists and Nobel laureates Daron Acemoglu and Simon Johnson insightful book **Power and Progress**.[1] More important than being intelligent, efficient, or anything else, computer systems should above all enhance the human experience.

The second big theme of this book is something we often take for granted: how to use gains in **efficiency** to land a positive impact in society. The term "efficiency" today often rings like a 1950s corporate term for things running smoothly and economically. That is true, in part, but this term is woefully in need of modernization for today's day and age, especially as it is used in the context of modern technologies. Computers were first developed to improve the efficiency of numerical computations, and eventually evolved to create efficiencies in virtually all aspects of human life. Essentially, over time, we have been able to do more with less. It is my contention that the problems we face as a society, such as global climate change, hunger, healthcare, growth and productivity, at their core, are problems of efficiency. These complex problems yearn

[1] *Power and Progress: Our Thousand-Year Struggle Over Technology and Prosperity,* D. Acemoglu and S. Johnson, PublicAffairs, 2023.

for efficiency-oriented solutions such as more efficient manufacturing, agriculture, pharmacology, and industries.

This book is the meditation of a computer scientist. I've set out to write a self-help book for this and future digital generations. How do we develop our human agency even as we become increasingly technologically efficient? I'm a big believer that human agency and efficiency must evolve concurrently to create a better world.

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It's no news to anyone that our lives are becoming ever more dependent on technology. We are in the middle of the AI revolution and on the verge of the quantum computing revolution. The better we understand the technologies shaping our lives today, the better positioned we will be to guide future technology use. This book was born out of my intent to explain the key concepts behind computer systems, with the hope of demystifying our fear of algorithms and helping us understand how they can be instrumental in creating a brighter future, with a more equitable and prosperous society.

It may be difficult for many of us to realize how much of our daily activities are simplified, amplified, or sometimes degraded, by computer systems. When we listen to music while driving to work, how many systems are we interacting with? If somehow the system is glitchy, and we cannot play our Spotify playlists, what is really happening? I wanted to give people the tools to understand what is going on under the covers. A Caltech faculty once asked physicist and Nobel laureate Richard Feynman, to explain a difficult concept in theoretical physics. After thinking about the problem for a few days, he came up with the opening quote for this book.[2] Given our current dependency on computer systems, and the expectation that such dependency will only increase, I want to explain the foundational elements to enable people to understand technologies such as social media, web search, cloud computing, AI, and quantum computing.

Computer technology was primarily born to enable efficiency. The Manhattan project employed human computers, which were ordinary women and men, to do calculations. Before the first computers were operational, this was common practice. The ENIAC, which was the first programmable digital computer, was ten thousand times faster than the human computers employed by the Manhattan project. The efficiency in computation brought by the ENIAC was fundamental for the development of the atomic bomb and played a crucial role in the Cold War, where it was used for various projects, including development of the hydrogen bomb. Since then, the continued development of computer technologies has widened the gap between human and digital computers. The efficiencies produced by computer systems have allowed us to achieve more in faster and more accessible ways. We have better and faster news access. We shop online. We have cybersecurity systems. The current AI revolution, for instance, has only been possible due to the abundance of computational resources enabled by cloud computing and due to the large amounts of data generated or captured by computer systems.

[2] https://magazine.caltech.edu/post/feynman-at-100 (Last accessed in March 2025).

As I will argue in this book, computers are merely capable of making computations more efficient. Computers alone are not able to increase efficiency in society. We need human creativity and agency to transform computational efficiencies into real-world positive impacts on society.

Important questions about the future of humanity hinge on efficiency tradeoffs. Are we going to push for a society that focuses on doing more with less above all else, or will we consider how technology can be used to augment our humanity? South Korea exemplifies a high-efficiency society shaped by post-war urgency, Confucian values, and a tech-driven economy. The country boasts world-class infrastructure, ultra-fast internet, and a highly disciplined education and work culture that fuel innovation and global cultural influence. However, this relentless focus on speed and productivity comes at significant social costs, including long work hours, extreme academic pressure, mental health challenges, and the world's lowest birth rate. While South Korea's coordinated systems and national cohesion have enabled rapid progress, the country now faces a critical balancing act between maintaining its global edge and ensuring societal well-being and sustainability.[3]

We can automate boring, tedious tasks we don't like doing. Computers are great at those, and they also don't complain about doing the same tasks over and over. Computers can also make us smarter. The newer generations of chess players are likely better than those that couldn't play against computers, or any opponent, for that matter, anytime they wished. Other uses of technology, unfortunately, can negatively impact society. The effect of social networks on teenagers' mental health may be the most evident example. The initial intent and excitement of being able to efficiently connect people across the globe may have ignored important tradeoffs. Of course, it may not have been possible to anticipate the consequences of social networks before they were used, this can be used as lessons learned going forward. While I don't claim to resolve every issue here, I hope to offer a useful perspective, including historical perspectives. The more we understand about the underpinnings of technologies that power the computer systems that impact our lives, the more agency we gain to shape them in ways that serve us. This is the basis of human agency.

I have spent most of my career working on the infrastructure for search engines and cloud computing services. Many of the projects I worked on are related to efficiency, answering questions like: how to make search queries faster? How to enable search engines to use fewer computational resources? How to democratize cloud service usage by lowering their costs? How to make cloud computing more sustainable by using energy more efficiently? And how to design an organization to execute these projects in a cost effective way? These efficiencies are enablers for us to tackle the world's most relevant problems. By managing computational resources better, cloud providers enabled fundamental advances in AI, which in turn allowed us to make progress on basic science at a faster rate. As an anecdotal example, the 2024 Nobel Prize in chemistry was awarded to researchers working on AI to advance our understanding of proteins and predicting their structures. Such capabilities can be utilized for research and

[3] https://www.ft.com/content/6e70f7bd-e311-41df-94fe-7a5575493ae6 (Last accessed in May 2025).

development that are fundamental for understanding biological mechanisms and the treatment of complex diseases, such as Alzheimer's disease.

I tried to present the concepts and algorithms described in this book in simple terms, with the intent to reach a wider audience, including readers that don't have a computer science background but are interested in learning more about the topic. I hope this book will inspire people to try to understand computer systems at a deeper level. Since I could not cover every possible computer system in a single book, I chose to focus on a few technologies that have, or will likely have, a huge impact on our lives: social media, web search, cloud computing, AI, and quantum computing. I strived to present the technical concepts in an increasing order of difficulty. Starting with simple algorithms, our journey goes through the avenues of sorting, compression, distributed systems, and NP-hard problems. Chapter 1 starts by defining some basic concepts which are used throughout the book. After that, each chapter introduces a new technology, building on the concepts previously described.

The last topics, AI and quantum computing, are the most complex, but by then we will have the tools to understand them more deeply. Technical readers will notice that I opted for clarity of presentation over completeness of some concepts. For instance, when talking about web search, I omit the use of caches to reduce the number of queries reaching the backends. I intentionally opted to go over more subjects at a shallower level, as opposed to conveying a smaller number of areas at a deeper level. Interested readers will find plenty of resources to dive deep into algorithms and systems they find interesting. I tried, as much as possible, to present technologies in chronological order, from the early days of the internet to today.

Chapter 5, on organizational efficiency, doesn't describe a new technology. In that chapter, instead of computer systems, I discuss how to run organizations to produce the most value, at the lowest possible cost by building on and incorporating the concepts outlined in the rest of the book. My motivation to include this chapter was twofold. First, it provides a systematic approach for the organizational productive cycle. Innovations that generate efficiencies allow us to reinvest our gains on innovations that produce value, generating a virtuous cycle for organizations. Second, it gives us a good foundation to talk about the effects of AI in productivity. Perhaps one of the most foundational questions we need to answer as a society is how will the new AI systems affect the way we work. And given that, what changes should be done to the educational system to prepare for such a workforce. Chapter 5 provides a foundation for that discussion.

Writing this book has been one of the most interesting projects of my professional career. As Richard Feynman said, it is challenging to present complex concepts at the freshman level. And although I know that no one can become an expert in computer science by reading a book, hopefully people will find the topics presented here interesting regardless of their level of technical knowledge. Most importantly, I hope the book is fun and that it helps broaden our collective understanding about technology, and how it can have a positive effect in our lives.

In order to help understand some of the technical concepts, I built an accompanying website, https://digitalagencybook.org, that shows visualizations for some of the algorithms I described throughout the book. Finally, all the author proceeds from this book are donated through Microsoft Philanthropies to causes related to the democratization of computer science education.

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