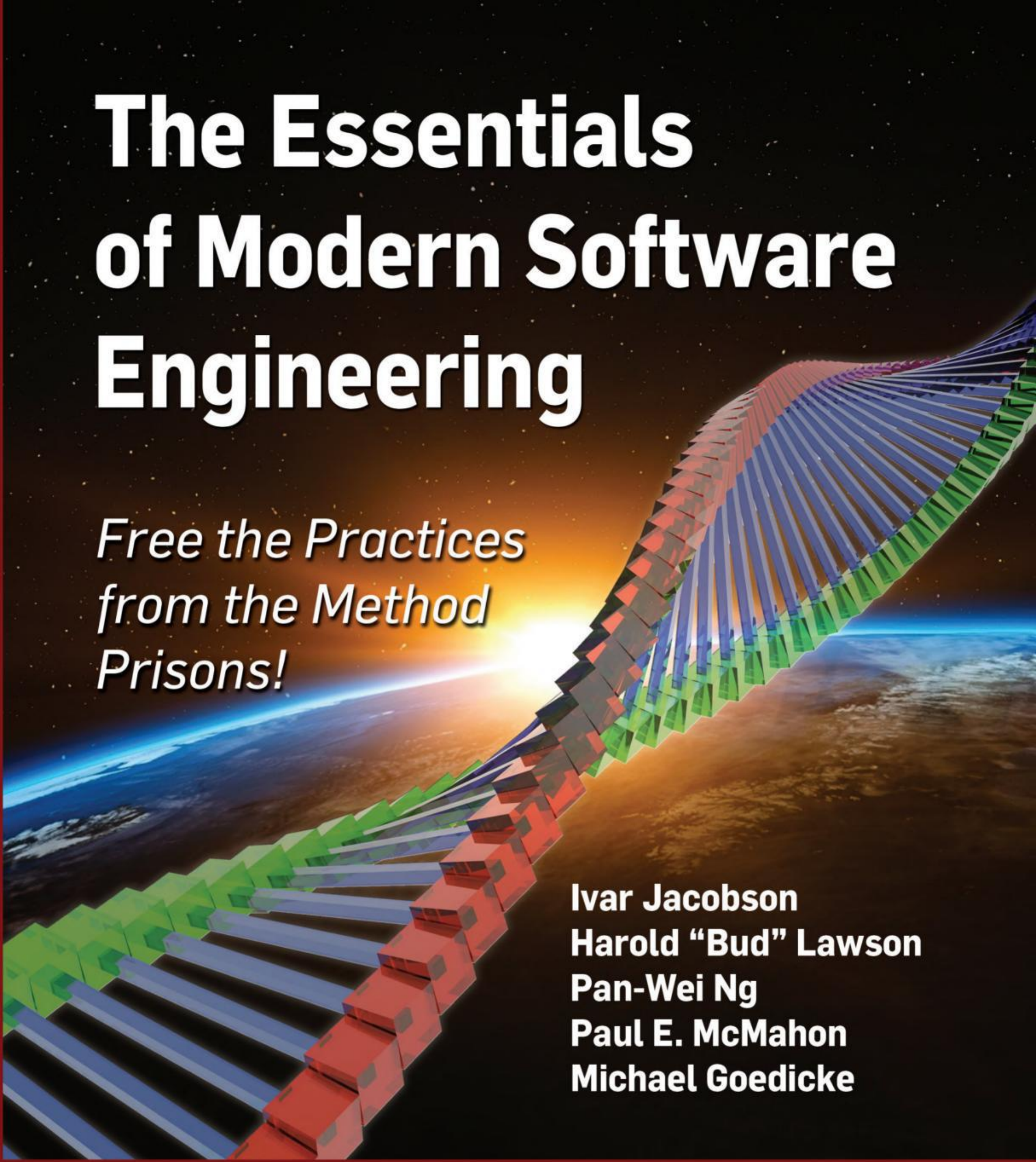

The Essentials of Modern Software Engineering

Free the Practices from the Method Prisons!

Ivar Jacobson
Harold "Bud" Lawson
Pan-Wei Ng
Paul E. McMahon
Michael Goedicke

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books.acm.org
www.morganclaypoolpublishers.com

ISBN: 978-1-94748-727-7 hardcover
ISBN: 978-1-94748-724-6 paperback
ISBN: 978-1-94748-725-3 eBook
ISBN: 978-1-94748-726-0 ePub

Series ISSN: 2374-6769 print 2374-6777 electronic

DOIs:

10.1145/3277669	Book	10.1145/3277669.3277685	Part III
10.1145/3277669.3277670	Preface	10.1145/3277669.3277686	Chapter 13
10.1145/3277669.3277671	Part I	10.1145/3277669.3277687	Chapter 14
10.1145/3277669.3277672	Chapter 1	10.1145/3277669.3277688	Chapter 15
10.1145/3277669.3277673	Chapter 2	10.1145/3277669.3277689	Chapter 16
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A publication in the ACM Books series, #25
Editor in Chief: M. Tamer Özsu, *University of Waterloo*
Area Editor: Bashar Nuseibeh, *The Open University*

This book was typeset in Arnhem Pro 10/14 and Flama using ZzTEX.

First Edition

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Foreword by Ian Sommerville

There's some debate over whether the term *software engineering* was first coined by Margaret Hamilton at NASA in the 1960s or at the NATO conference at the end of that decade. It doesn't really matter because 50 years ago it was clear that software engineering was an idea whose time had come.

Since then, developments in software engineering have been immense. Researchers and practitioners have proposed many different methods and approaches to software engineering. These have undoubtedly improved our ability to create software, although I think it is fair to say that we sometimes don't really understand why. However, we have no basis for comparing these methods to see if they really offer anything new and we can't assess the limitations of software engineering methods without experiencing failure. Although we are a lot better at developing software than we were in the 20th century, it is still the case that many large software projects run into problems and the software is delivered late and fails to deliver the expected value.

The SEMAT initiative was established with the immense ambition to rethink software engineering. Rather than inventing another new method, however, Ivar Jacobson and his collaborators went back to first principles. They examined software engineering practice and derived a common underlying language and kernel (Essence) that could be used for discussing and describing software engineering. Essence embodies the essential rather than the accidental in software engineering and articulates new concepts such as alphas that are fundamental to every development endeavor.

Essence is not a software engineering method but you can think of it as a meta-method. You can use it to model software engineering methods and so compare them and expose their strengths and weaknesses. More importantly, perhaps, Essence can also be the starting point for a new approach to software engineering. Because of the universality of the concepts that it embodies, Essence can be used across a much wider range of domains than is possible with current methods.

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It wisely separates the notion of specific practices, such as iterative development, from fundamental concepts so it can be used in a variety of settings and application domains.

The inventors of Essence understand that the value of Essence can only be realized if it is widely used. Widespread use and experience will also expose its limitations and will allow Essence to evolve and improve. This book is an important contribution to transferring knowledge about Essence from specialists to a more general audience. Although notionally aimed at students, it provides an accessible introduction to Essence for all software engineers.

Organized into four parts, the first three parts focus squarely on using Essence as a means of thinking about, planning, and describing software development. Using real but manageable examples, Parts I and II of the book cover the fundamentals of Essence and the innovative use of serious games to support software engineering. Part III explains how current practices such as user stories, use cases, Scrum, and microservices can be described using Essence and shows how their activities can be represented using the Essence notions of cards and checklists. Part IV is perhaps more speculative but offers readers a vision of how Essence can scale to support large, complex systems engineering.

Software engineering has been both facilitated and hampered by the rate of technological innovation. The need to build software for new technologies has led to huge investment in the discipline but, at the same time, has made it difficult to reflect on what software engineering really means. Now, 50 years on, Essence is an important breakthrough in understanding the meaning of software engineering. It is a key contribution to the development of our discipline, and I'm confident that this book will demonstrate the value of Essence to a wider audience. It, too, is an idea whose time has come.

Ian Sommerville

Emeritus Professor of Software Engineering at St. Andrews University, Scotland. For more than 20 years, his research was concerned with large-scale complex IT systems. He is the author of a widely used textbook on software engineering, titled *Software Engineering*, first published in 1982, with the 10th edition published in 2015.

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Foreword by Grady Booch

The first computers were human; indeed, the very noun "computer" meant "one who computes or calculates" (and most often those ones were women).

My, how the world has changed.

Computing has woven itself into the interstitial spaces of society. Software-intensive systems power our cars and airplanes; they serve as our financial conduits; they track our every action; they fight our wars; they are as intimate as devices we hold close to us or even within us and as grand as the wanderers we have flung into space and that now inhabit other planets and venture to other stars. There is no other invention in the history of humanity that has such a potential to amplify us, diminish us, and perhaps even replace us.

I have often observed that the entire history of software engineering can be characterized as the rising levels of abstraction. We witness this in our programming languages, in our tools, in our frameworks, in the very ways with which we interact with software-intensive systems . . . and even in the ways in which we craft these systems. This is the world of software engineering methods.

I am proud and humbled to call myself a friend of Ivar Jacobson. The two of us, along with Jim Rumbaugh, were at the center of a sea change in the way the world develops and deploys software-intensive systems. We got some things right; we got some things wrong. But, most important, we helped to codify the best practices of software engineering in their time. Indeed, that was an incredibly vibrant time in the history of software engineering, wherein many hundreds if not thousands of others were struggling with how to codify the methods by which systems of importance could best be built.

The nature of software development has changed—as it should and as it will again—and even now we stand at an interesting crossroads in the field. Agile methods have proven themselves, certainly, but we are at the confluence of technical and economic forces that bring us again to a very vibrant point in time. As the Internet of Things brings computing to billions of devices, as computational resources grow

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in unceasing abundance, and as deep learning and other forms of artificial intelligence enter the mainstream, now is the time to establish a sound foundation on which we can build the next generation of software-intensive systems that matter.

In a manner of speaking, one might say that the *essence* of Essence is its powerful mastery of the fundamental abstractions of software engineering. I saw in Ivar the seeds of Essence in the early days of working with him and Jim on the UML, and so now it is wonderful to see this work in its full flowering. What you hold in your hands (or on your computer or tablet, if you are so inclined) represents the deep thinking and broad experience of Ivar; information that you'll find approachable, understandable, and—most importantly—actionable.

Enjoy the journey; it will make a difference for the good.

Grady Booch

IBM Fellow, ACM Fellow, IEEE Fellow, recipient of the BCS Ada Lovelace Award, and IEEE Computer Pioneer.

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Preface

We have developed software for many years, clearly more than 50 years. Thousands of books and many more papers have been written about how to develop software. Almost all teach one particular approach to doing it, one which the author thinks is the best way of producing great software; we say each author has canned his/her method. Most of these authors have some interesting ideas, but none can help you in all the circumstances you will be faced with when you develop software. Even the most modern books take this approach of presenting and selling “the one true way” of doing it. Unless you are a world leader ready to impose your own true way of doing it, all other top experts in the world seem to be in agreement that this proprietary approach is not the way to teach software development to students.

You now have in front of you a book that will teach you modern software engineering differently from how the subject has been taught since its infancy. On one hand, it stands on the shoulders of the experience we have gained in the last 50 years or more. On the other hand, it teaches the subject in a universal and generic way. It doesn’t teach you one particular way of developing software, but it teaches you *how to create* one way of working that matches your particular situation and your needs. The resulting way of working that you create is easy to learn (intuitive), easy to adopt (by a team), easy to change (as you learn more), and fun to work with thanks to its user experience being based on games and playing cards.

It is worth repeating: This book does not primarily teach you one particular way of developing great software; rather, it teaches you how to create such a way of working that should result in great software.

How This Book Is Different from Other Software Engineering Textbooks

On the surface this book looks like most other books in software engineering (and there are many of them; some are excellent books). It describes many important

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aspects of software engineering and how a typical software engineering initiative resulting in a new or improved software product takes place. However, underneath the surface, this book is fundamentally different. The things being described are selected because they are prevalent in every software engineering initiative. They are the essential things to work with, the essential things to do, and the essential competencies needed when you develop software. They are not just examples of things or typical things. They are selected because they are the things that underpin all recognized ways of developing software. The selection has been made by a group of experts from around the world representing academia, research, and industry, under the auspices of an international group called Object Management Group that gave rise to the Essence standard.[1]

Essence addresses, first and foremost, a number of serious challenges we have in the software industry today, one of which is that for 50 years we have had a war between the canned methods (but there are many more challenges, which we will discuss in the book). In addressing these issues, Essence has made it possible to systematically improve the way we work, which should result in better software—faster and cheaper. However, this will have to wait to be discussed until you have gone deeper into the book.

Finally, the following summary can be repeated over and over again.

- Essence supports people when working with methods and it helps people while they actually work developing software.
- Essence is not yet another method. It is many things but not a method competing with any other method.
- It is a foundation to be used to describe methods effectively and efficiently.
- It is a thinking framework to be used when creating your method or using your method, whether it is explicit or tacit.
- It can help you in a method-agnostic way to measure progress and health in your endeavor.[2]
- It can help you, if you have challenges, to find root causes of the problems with your endeavor.

1. Essence has been likened to the DNA of software engineering or the periodic table in chemistry.

2. Throughout this book, except for the cases where the term *project* is more appropriate for historical reasons, we use the term *endeavor*. This is because not all software development occurs within the context of a formal project.

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How This Book Can Help Students

If you are a student, this book will play a significant role in your career, because from this book you will learn the fundamentals of the complex discipline of software engineering. Even if you are not a student, you will rediscover your discipline in a way you never expected. This is no ordinary software engineering textbook. What you will learn from this book you can take with you wherever you go, for the rest of your software engineering career.

Other books will help you learn the latest technologies, practices, and methods. While you will need that kind of information as you go through your career, their value will fade over time as new technologies, practices, and methods come into play. There is nothing wrong with that. Part of our profession is continuous improvement and we encourage and expect that to go on forever.

What You Will Learn from This Book

So that you have the right expectations, we want to tell you what you can expect to learn from this book.

- You will learn what are the essentials of software engineering presented as a common ground.
- You will learn a simple, intuitive language by which you can describe specific ways of working, called practices, using the common ground as a vocabulary.
- You will learn how the common ground can be used to assess the progress and health of your software development endeavors no matter how simple or complex.
- You will learn "lite" versions of a number of practices that are popular at the time of writing this book, *but they are only meant as examples to demonstrate how to use the common ground and the language to describe practices.*
- You will learn how to improve your way of working by adding or removing practices, as and when the situation demands.
- You will learn how to improve communication with your teammates.

To be clear, this is what you won't learn from this book.

- You will not learn any fully developed practices to be used in a real endeavor (in a commercial production environment), since what we teach here is not

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intended for that purpose. To learn practices that will work in such an environment, you need to go to practice libraries such as the Ivar Jacobson International practice library (https://practicelibrary.ivarjacobson.com/start) or, if the practices are not yet essentialized, you will have to go to books or papers written about these practices.

- You will not learn the latest technologies, practices, and methods.

This book is about learning a foundation that underlies all practices and methods that have come and gone during the last 50 years, and all that will likely come and go over the next 50 years. What you learn from this book you can take with you, and it will continue to help you grow throughout your software engineering career.

Our Approach to Teaching in This Book

We also want to share with you a little bit about the approach to teaching software engineering that we use in this book. While we do share some of the history of software engineering in Part I and in the appendix, our general approach throughout the book is a bottom-up approach instead of a top-down one. The "user" is a young student and he/she is presented with more and more advanced use cases of software development—from small systems to large systems. Or said in another way, we present the essence of software engineering through the eyes of a young student who moves from introductory courses into the industry. This approach will help you understand how software engineering is often first viewed by new software developers and how their perceptions and understanding of software engineering grow with their experiences.

So with this brief introduction, you are now ready to start your exciting journey toward the essentials of modern software engineering. During the journey, you will pass through the following.

Part I, The Essence of Software Engineering. Here, we introduce the student to software engineering and to the Essence standard.

Part II, Applying Essence in the Small. Here, Essence is first used to carry out some simple, small, but very useful practices. They are so small that they could be called mini-practices, but we call them games—serious games. They are highly reusable when carrying out practices resulting in, for instance, software products.

Then in the rest of this part we advance the problem and consider building some real but rather small software. We make the assumption that the given team members have worked together before, so they have tacit knowledge

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about the practices they use and don't need any additional explicit guidance in the form of described practices.

Part III, Small-Scale Development with Practices. We use practices defined on top of the kernel to provide further guidance to small teams.

Part IV, Large-Scale Complex Development. To describe how to develop large software systems is far too complex for a textbook of this kind. However, we do explain the impact large teams and organizations have on the practices needed and how they are applied.

Appendix, A Brief History of Software Engineering.

On our website, http://software-engineering-essentialized.com, you are provided with additional training material and exercises associated with each part of the book. This website will be continuously updated and will provide you with additional insight. As you gain experience, we hope you will also be able to contribute to this growing body of knowledge.

How This Book Can Free the Practices from the Method Prisons and Why This Is Important

In 1968, more than 50 years ago, the term *software engineering* was coined to address the so-called software crisis. Thousands of books have been written since then to teach the "best" method as perceived by their authors. Some of them have been very successful and inspired a huge number of teams to each create their own method. The classical faith typically espoused by all these popular methods has been that the previous popular method now has become completely out of fashion and must be replaced by a new, more fashionable method. People have been swinging with these trends and, apart from learning something new, each time they must also relearn what they already knew but with just a new spin to it.

The problem is that among all these methods there has been almost nothing shared, even if in reality much more has been shared than what separated them. What they shared was what we will call practices—some kind of mini-methods. Every method author (if very successful, each became a guru) had their own way of presenting their content so that other method authors couldn't simply reuse it. Instead, other authors had to reinvent the wheel by describing what could have been reusable—the practices—in a way that fit these other authors' presentation styles. Misunderstandings and improper improvements happened and the method war was triggered. It is still going on. Instead of "standing on one another's shoulders," these various authors are "standing on one another's toes."

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This book will show how reusable practices can be liberated from the methods that use them—their method prisons. Free the practices from the method prisons!

Acknowledgments

Special thanks and acknowledgment goes to Svante Lidman and Ian Spence for their work on the first Essence book [Jacobson et al. 2013a], from which some pieces of text have been used, to Mira-Kajko-Mattson for her role in the original shaping of this book, to Pontus Johnson for his work on theory in Part I, Chapter 7 and to Barbora Buhnova for in particular her clear and accurate writing of the goal and the accomplishments paragraphs in each chapter of the book. All these contributions improved the clarity of the book as a whole.

The authors also want to recognize and thank all the people that worked with us in creating the OMG Essence standard and in working on its use cases. Without these individuals' work this book would never have been written:

- For founding the SEMAT (Software Engineering Method And Theory) community in 2009 and later leading it: Apart from Ivar Jacobson, the founders were Bertrand Meyer and Richard Soley. June Park chaired the SEMAT community from 2012 to 2016 and Sumeet Malhotra from 2016 until now.
- For serving as members of the Advisory Board chaired by Ivar Jacobson: Scott Ambler, Herbert Malcolm, Stephen Nadin, Burkhard Perkens-Colomb.
- For supporting the foundation of the SEMAT initiative and its call for action:
    - Individuals: Pekka Abrahamsson, Scott Ambler, Victor Basili, Jean Bézivin, Robert V. Binder, Dines Bjorner, Barry Boehm, Alan W. Brown, Larry Constantine, Steve Cook, Bill Curtis, Donald Firesmith, Erich Gamma, Carlo Ghezzi, Tom Gilb, Robert L. Glass, Ellen Gottesdiener, Martin Griss, Sam Guckenheimer, David Harel, Brian Henderson-Sellers, Watts Humphrey, Ivar Jacobson, Capers Jones, Philippe Kruchten, Harold "Bud" Lawson, Dean Leffingwell, Robert Martin, Bertrand Meyer, Paul Nielsen, James Odell, Meilir Page-Jones, Dieter Rombach, Ken Schwaber, Alec Sharp, Richard Soley, Ian Sommerville, Andrey Terekhov, Fuqing Yang, Edward Yourdon.
    - Corporations: ABB, Ericsson, Fujitsu UK, Huawei, IBM, Microsoft Spain, Munich RE, SAAB, SICS, SINTEF, Software Engineering Institute (SEI), Tata Consulting Services, Telecom Italia, City of Toronto, Wellpoint.

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    - Academics: Chalmers University of Technology, Florida Atlantic University, Free University of Bozen Bolzano, Fudan University, Harbin Institute of Technology, Joburg Centre for Software Engineering at Wits University, KAIST, KTH Royal Institute of Technology, National University of Colombia at Medellin, PCS—Universidade de São Paulo, Peking University, Shanghai University, Software Engineering Institute of Beihang University, Tsinghua University, University of Twente, Wuhan University.

- For developing what eventually became the Essence standard with its use cases and for driving it through the OMG standards process: Andrey Bayda, Arne Berre, Stefan Bylund, Dave Cuningham, Brian Elvesæter, Shihong Huang, Carlos Mario Zapata Jaramillo, Mira Kajko-Mattson, Prabhakar R. Karve, Tom McBride, Ashley McNeille, Winifred Menezes, Barry Myburgh, Gunnar Overgaard, Bob Palank, June Park, Cecile Peraire, Ed Seidewitz, Ed Seymour, Ian Spence, Roly Stimson, Michael Striewe.
- For organizing SEMAT Chapters around the world: Doo-Hwan Bae, Steve Chen, Zhong Chen, Barry Dwolatsky, Gorkem Giray, Washizaki Hironori, Debasish Jana, Carlos Mario Zapata Jaramillo, Pinakpani Pal, Boris Pozin.
- For co-chairing the "Software Engineering Essentialized" project with Ivar Jacobson: Pekka Abrahamsson. This project develops training material, quizzes, exercises, certification, games, essentialized practices, etc. to support teachers giving classes based on this book.

From the outset of the writing of this book, the authors were aware of the fundamental change they proposed to the education in software engineering. Therefore, they wanted the book to be meticulously reviewed before publication. The book has been reviewed in 5 phases, each being presented as a draft. About 1000 comments have been given by more than 25 reviewers and each comment has been discussed and acted upon. We are very grateful for the help we received from the following people (alphabetically ordered) in making this a book we are very proud of: Giuseppe Calavaro, A. Chamundeswari, Görkem Giray, Emanuel Grant, Debasish Jana, Eréndira Miriam Jiménez Hernandez, Reyes Juárez-Ramírez, Winifred Menezes, Marcello Missiroli, Barry Myburgh, Anh Nguyen Duc, Hanna Oktaba, Don O'Neill, Gunnar Overgaard, Pinakpani Pal, Cecile Peraire, Boris Pozin, Antony Henao Roqueme, Anthony Ruocco, Vladimir Savic, Armando Augusto Cabrera Silva, Kotrappa Sirbi, Nebojsa Trninic, Hoang Truong Anh, Eray Tüzün, Murat Paşa Uysal,

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Ervin Varga, Monica K. Villavicencio Cabezas, Bernd G. Wenzel, Carlos Mario Zapata Jaramillo.

As you can see from these acknowledgments, many people have contributed to where we are today with Essence and its usage. Some people have made seminal technical contributions without which we wouldn't have been able to create a kernel for software engineering. Some other people have contributed significant time and effort to move these technical contributions into a high-quality standard to be widely adopted. Some people have been instrumental in identifying the vision and leading the work through all the pitfalls that an endeavor can encounter when it is as huge as the SEMAT in fact is. Finally, some people have made huge efforts and with high passion marketed the work and the result to break through the barriers that fundamentally new ideas always face. We have not made an effort to rank all these contributions here, but we hope all these individuals are assured that we know about them and we are tremendously grateful for all they have done.

We would also like to thank the team at Windfall Software for carefully copy editing and preparing the content of this book. We are especially grateful to their professional developmental editor, who was instrumental in this endeavor and put in a huge effort to achieve this high-quality result.

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PART I

THE ESSENCE OF SOFTWARE ENGINEERING

We live at an exciting time in the history of computer and network technologies where software has become a dominant aspect of our everyday life. Wherever you look and wherever you turn, software is there. It is in almost everything you use and affects most everything you do. Software is in many things such as microwaves, ATMs, smart TVs, machines running vehicles, and factories, as well as being utilized in all types of organizations.

Although software provides many opportunities for improving many aspects of our society, it presents many challenges as well. One of them is development, deployment, and sustainment of high-quality software on a broad scale. Another is the challenge of utilizing technology advancements in new domains, for instance, intelligent homes and Smarter Cities. Here, the evolution of the mobile internet, apps, the internet of things (IoT), and the availability of big data and cloud computing, as well as the application of artificial intelligence and deep learning, are some of the latest "game-changers" with more still to come.

This book provides you with fundamental knowledge you will need for addressing the challenges faced in this era of rapid technology change. Part I will introduce you to software engineering through the lens of a kernel of fundamental concepts that have been provided by the Object Management Group's standard called Essence 1. Essence is rapidly becoming a "lingua franca" for software engineering. The authors are convinced that this approach will provide a perspective that will be a lasting contribution to your knowledge base and prepare you to participate in teams that can develop and sustain high-quality software.

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From Programming to Software Engineering

This chapter sets the scene with respect to the relationship between programming und software engineeering. The important issue is that software engineering is much more than just programming. Of course, the running system created by an act of programming is an essential and rewarding ingredient of what the right system will become, and it is important that the reader is actually able to use and apply a programming language to create a program, at least a small one. But is it by no means everything. Thus, this chapter

- introduces the notion of software development and that it is more than just putting a program together;
- shows what additionally is needed beyond programming, i.e., shows the differences between programming, software development, and software engineering;
- shows the motivations for the discipline of software engineering;
- introduces some important elements of software engineering that actually show the differences between software engineering and programming, and shows how they relate to each other.

What is fascinating about this aspect of software development is that it is more than just programming. Rather, it is to learn the whole picture and as a software engineer to solve a problem or exploit an opportunity that the users may have.

As a new student, understanding what software engineering is about is not easy, because there is no way we can bring its realities and complexities into the student's world. Nevertheless, it is a student's responsibility to embark on this journey of learning and discovery into the world of software engineering.

Throughout this entire book, we will trace the journey of a young chap, named Smith, from his days in school learning about programming through to becoming

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Sidebar 1.1 Programming

Programming is used here as a synonym for *implementation* and *coding*. From Wikipedia we quote: "Related tasks include testing, debugging, and maintaining the source code, ... These might be considered part of the programming process, but often the term *software development* is used for this larger process with the term *programming*, *implementation*, or *coding* reserved for the actual writing of source code."

a software engineering professional and continuing his on-going learning process in this ever-changing and growing field. In a way, we are compressing time into the pages of this book. If you are a new student, you are considered to be the primary audience for this book. Smith will be your guide to the software engineering profession, to help you understand what software engineering is about. If you are already a software engineer by profession, or you teach and coach software engineering, you can reflect on your own personal journey in this exciting profession. As an experienced developer you will observe an exicting and fundamentally new way to understand and practice software engineering. Regardless of your current personal level of experience, through Smith's experiences we will distill the essence of software engineering.

1.1 Beginning with Programming

The focus of our book is not about programming (see Sidebar 1.1), but about software engineering. However, understanding programming is an obvious place to start. Before we delve deeper into it, we should clarify the relation of programming to software development and to software engineering.

Thus we have chosen the following.

- *Programming* stands for the work related to implementation or coding of source code.
- *Software development* is the larger process which, apart from programming, includes working with requirements, design, test, etc.
- "*Software engineering* combines engineering techniques with software development practices" (from Wikipedia). Moving from development to engineering means more reliance on science and less on craft, which typically manifests itself in some form of description of a designated way of working and higher-level automation of work. This allows for repeatability and consistency from project to project. Engineering also means that teams, for example, learn as they work and continuously improve their way of work-

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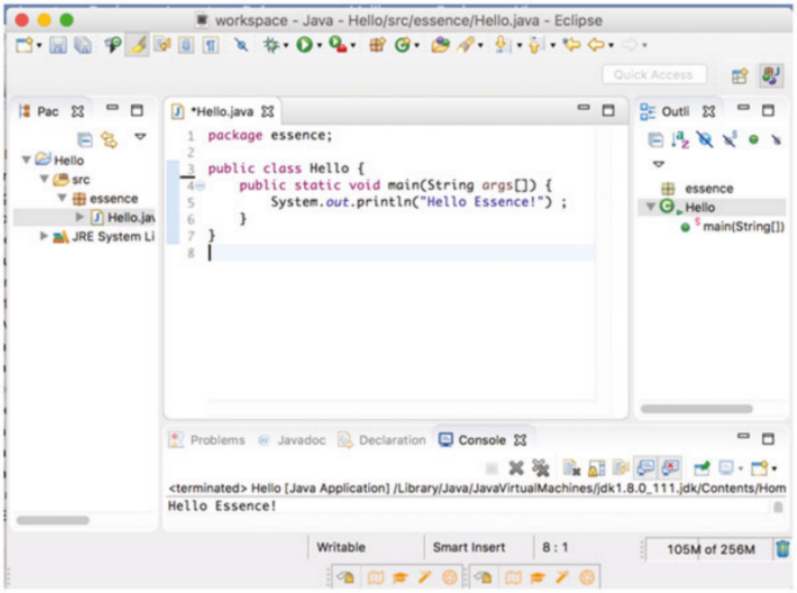
ing. Thus, stated in simple terms, *software engineering is bringing engineering discipline to software development.*

Going forward, when introducing software engineering we will mean the larger subject of “software development + engineering,” implicitly understood without specifically separating out the two parts. This will be so even if in many cases the discussion is more about the development aspect, because the approach we take is chosen to facilitate the other aspect—engineering. When we sometimes talk about software development we want to be specific and refer to the work: the activities or the practices we use. We will not further try to distinguish these terms, so the reader can in many cases see them as synonyms.

As a frequent user of applications like Facebook, Google, Snapchat, etc., whether on his laptop or his mobile, Smith knew that software forms a major component in these products. From this, Smith became strongly interested in programming and enrolled in a programming course where he started to understand what program code was and what coding was all about. More importantly, he knew that programming was not easy. There were many things he had to learn.

The very first thing Smith learned was how to write a program that displays a simple “Hello World” on his screen, but in this case, we have a “Hello Essence!”, as in Figure 1.1. Through that he learned about programming languages,



```
package essence;

public class Hello {
    public static void main(String args[]) {
        System.out.println("Hello Essence!") ;
    }
}
```

```
<terminated> Hello [Java Application] /Library/Java/JavaVirtualMachines/jdk1.8.0_111.jdk/Contents/Hom
Hello Essence!
```

Figure 1.1 Hello Essence.

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programming libraries, compilers, operating systems, processes and threads, classes, and objects. These are things in the realm of computer technology. We expect that you, through additional classes, will have learned about these things. We also expect you as a student to have some knowledge of these things as a prerequisite to reading this book. We expect that you have some knowledge of programming languages like Java and JavaScript.

1.2 Programming Is Not Software Engineering

However, Smith quickly learned that programming on its own is not software engineering. It is one thing to develop a small program, such as the "Hello Essence" program; it is a different thing to develop a commercial product.

It is true that some fantastic products such as those that gave birth to Apple, Microsoft, Facebook, Twitter, Google, and Spotify once were developed by one or a few individuals with a great vision but by just using programming as a skill. However, as the great vision has been implemented, be sure that these companies are today not relying on heroic programmers. Today, these companies have hired the top people with long experience in software engineering including great programming skills.

So, what is software engineering? Before we answer this question, we must first make it very clear that there is a remarkable difference between hacking versus professional programming. Professional programming involves clear logical thinking, beginning with the objective of the program, and refining the objective into logically constructed expressions. Indeed, the expressions are a reflection of the programmers' thinking and analysis. Hacking on the other hand is an ad hoc trial and error to induce the desired effect. When the effect is achieved, the hacker marvels without really understanding why it worked. Professional programmers understand why and how it worked.

As such, professional programming is highly disciplined. Software engineering takes this discipline to software teams working on complex software. A typical software development endeavor involves more than one person working on a complex problem over a period of time to meet some objectives. Throughout Smith's introductory software engineering course, he worked on several assignments, which frequently required him to work with his fellow students, and which included tasks, such as:

1. brainstorming what an event calendar app would look like;
2. writing code for a simple event calendar in a small group;
3. writing code for the event calendar app, and hosting the app on the cloud;

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4. reviewing a given piece of code to find issues in it, for example bugs, and poor understandability; and
5. reviewing a fellow student's code.

Through these assignments, Smith came to several conclusions. First, there is no one true way to write code for a given problem. Writing good quality code that fellow students can understand is not easy. It often takes more than one pair of eyes to get it working and comprehensible. He learned the following.

- Testing, i.e., checking that the program behaves as intended, is not easy. There are so many paths that executing the code can follow and all have to be tested.
- Agreeing on what the application would do was challenging. Even for that simple event calendar app, Smith and his team debated quite a while before they came to a consensus on what functionality ought to be available, and how the user interface should be laid out.
- A simple application may require multiple programming languages. For example, the event calendar app would need HTML5 and JavaScript for the front end, and the Java and SQL database for the backend. Consequently, Smith found that he had to spend a significant amount of time learning and getting familiar with new programming languages and new programming frameworks. Although he endeavored to learn about all these, it was certainly not easy with the limited time that was available.
- Time management is not easy because it is hard to estimate how much time each activity will require—or when to stop fine-tuning a certain piece of code to meet time constraints of the project.

As Smith was preparing for his industry internship interview, he tried to summarize on a piece of paper, from those things he then understood, what software engineering is about, and what he had learned thus far. Smith drew what he understood many times, and he observed that he couldn't get it quite right. In the end, he settled for what is shown in Figure 1.2.

To Smith, software engineering was about taking some idea and forming a team according to the requirements. The team then transforms the requirements into a software product. To do this, the team engages in some kind of brainstorming, consensus, writing and testing code, getting to a stable structure, maintaining user satisfaction throughout, and finally delivering the software product. This requires the team to have competencies in coding, analysis, and teamwork. In addition,

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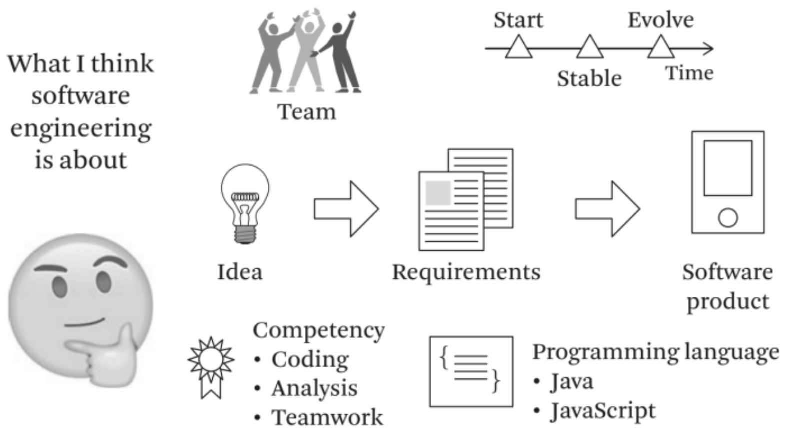

Figure 1.2 What software engineering is from the eyes of a student.

the team needs familiarity with some programming language, such as Java and JavaScript, which Smith knew. What Smith didn't yet know was that the tasks he had been given were still relatively simple tasks compared to what is typical in the software industry. Nevertheless, with this preparation, Smith marched toward his internship interview.

1.3 From Internship to Industry

With some luck, Smith managed to join the company TravelEssence as an intern trainee. Dave the interviewer saw some potential in Smith. Dave was particularly intrigued that Smith managed to draw the picture in Figure 1.2. Most students couldn't, and would get stuck if they even attempted to.

TravelEssence is a fictitious company that we will be using as an example throughout this book. TravelEssence provides online hotel booking services for travelers (see Figure 1.3). In addition, TravelEssence provides Software as a Service (SaaS) for the operation of hotels. SaaS means that the owner of the software, in this case TravelEssence, provides software as a service over the internet and the clients pay a monthly fee. Hotels can sign up and use the TravelEssence service to check-in and check-out their customers, print bills, compute taxes, etc.

Smith's stint in TravelEssence provided a whole new experience. To him, his new colleagues seemed to come from two groups: those who stated what they wanted the software to do, and those who wrote and tested the software. Figure 1.4 highlights the dramatic changes Smith experienced. While everyone seemed to speak English, they used words that he did not understand, especially the first group. As a diligent person, Smith compiled a list of some of this jargon.

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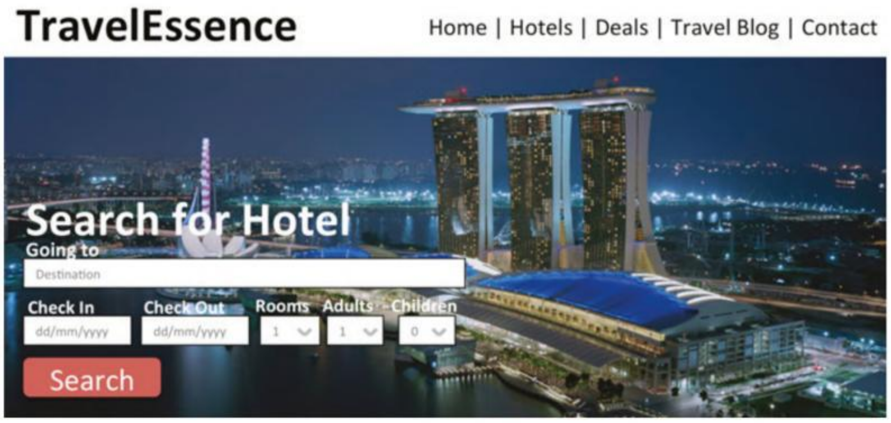

Figure 1.3 TravelEssence home page.

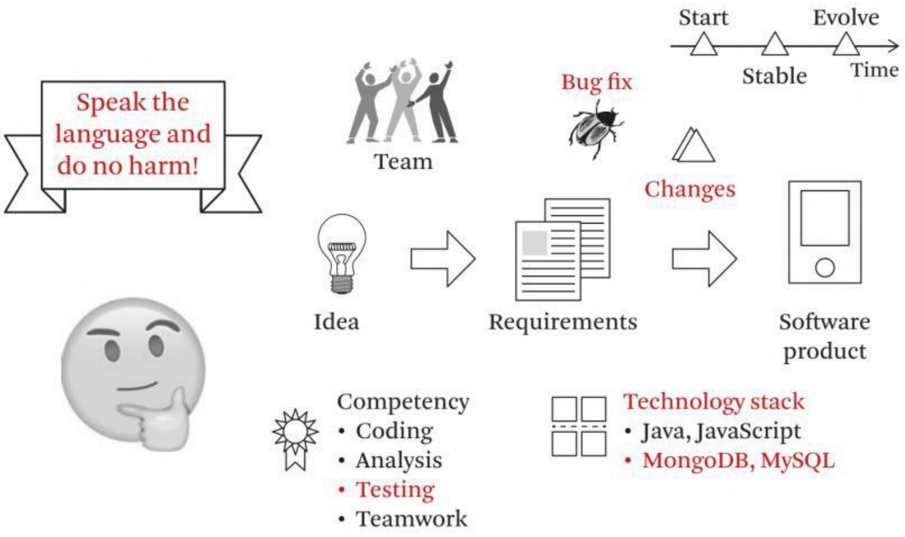

Figure 1.4 What software engineering is from the eyes of a student after internship.

Book. To sell or reserve rooms ahead of time.

No-Show. A guest who made a room reservation but did not check in.

Skipper. A guest who left with no intention of paying for the room.

PMS. Property Inventory Management System, which maintained records of items owned by the hotel such as items in each room including televisions, beds, hairdryers, etc.

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POS. Point of Sale Systems (used in restaurants/outlets) that automated the sale of items and managed purchases with credit or debit cards.

It took Smith a little while to get on "speaking terms" with his new colleagues and mentors.

In his student days, Smith always wrote code from scratch, starting with an empty sheet of paper. However, at TravelEssence it was mostly about implementing enhancements to some existing code. The amount of code that Smith saw was way above the toy problems he came across as a student. His development colleagues did not trust him to make any major changes to the system. Developers in TravelEssence emphasized code reviews heavily and stressed the importance of "Do no harm" repeatedly. They would repeatedly test his understanding of terminology and their way of working. Smith felt embarrassed when he could not reply confidently. He started to understand the importance of reviewing and testing his work. After his internship, Smith attempted to summarize what he understood software engineering to be (see Figure 1.4). This was quite similar to what he thought before his internship (see Figure 1.2), but with new knowledge (indicated in red) and an emphasis on testing and doing no harm as he coded changes to the software product. Smith came to recognize the importance of knowledge in different areas, not just about the code, but also about the problem domain (in this case, about hotel management), and the technologies that were being used.

Competency not only involved analysis, coding, and teamwork, but also extensive testing to ensure that Smith did no harm. Understanding programming languages was no longer sufficient; a good working knowledge of the technology stack was critical. A technology stack is the set of software technologies, often called the building blocks, that are used to create a software product. Smith was familiar with multiple technologies that were being used including Java, JavaScript, MongoDB, and MySQL. Never mind if you do not know these specific terms.

Note: There are myriads of technology stacks available, and it is not possible for anyone to learn them all. Nevertheless, our recommendation to students is to gain familiarity with a relevant technology stack of your choice.

Smith graduated and was employed at TravelEssence. A few years later, at a get-together, Smith and his old classmates shared their newfound experiences in the real commercial world. At this occasion Smith said: "At TravelEssence even though everyone seemed to be using different terminology, and everyone did things differently, there seemed to be something common to what they were all doing." One of his old classmates asked Smith if he could explain more, but Smith just shook his head and said, "I don't know exactly what it is."

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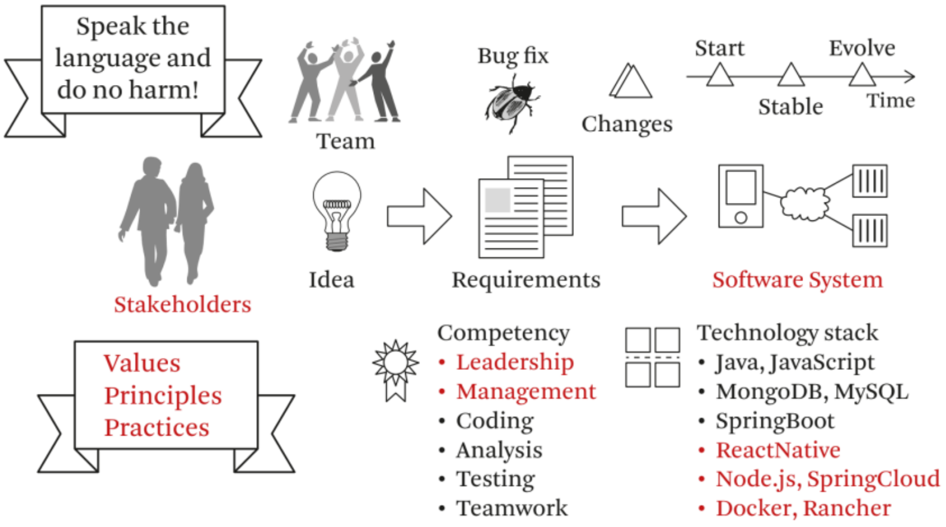

Figure 1.5 What software engineering is from the eyes of a young professional.

Some years later, Smith became a technical lead for a small group at TravelEssence. As a technical lead he found himself continuously thinking about that discussion with his old classmates as he tried to figure out just what it was that was common about the way everyone worked at TravelEssence.

One evening the old classmates got together again. This time the discussions were a blend between technologies and people management. The old classmates were also talking more about their experiences dealing with people including their colleagues, managers, and their customers; consequently, they were talking more about the way work got done in their organizations. Managing stakeholders and their expectations became more important as they started to take on more senior positions.

After the meeting with classmates, Smith started to draw what he then thought software engineering was about (see Figure 1.5). The changes compared to Smith's internship experience are highlighted in red.

Stakeholder collaboration played an important part of Smith's work. Collaborating well involved having an agreed-on set of values, principles, and practices. These values included agreeing upon a common goal, and respecting and trusting team members, as well as being responsible and dependable. All of these values are qualities of a good and competent team player. Principles include, for instance, having frequent and regular feedback, and fixing bugs as soon as they are detected. All of

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these principles identify good behaviors in a team. Practices are specific things the team will do to deliver what is expected of the team consistent with the above values and principles, as well as good quality software.

1.4 Journey into the Software Engineering Profession

Smith through his experience at TravelEssence thus far had started to appreciate the complexities involved in producing and sustaining high-quality software that meets the needs of stakeholders. He now appreciated that while programming is an important aspect, there is much more involved. It is the engineering discipline that is concerned with all aspects of the development and sustainment of software products.

Smith then reflected upon the knowledge he had attained thus far in his career. As a student with no other experience than having done some programming, it is quite difficult to understand what more is involved in software engineering. Typically, when creating a program in a course setting, the exercise starts from an idea that may have been explained in a few words: say, less than one hundred words. Based on the idea, Smith and his classmates developed a piece of software, meaning they wrote code and made sure that it worked. After the assignment they didn't need to take care of it. These assignments were small and to perform them they really did not need much engineering discipline. This situation is quite unlike what you have to do in the industry, where code written will stay around for years, passing through many hands to improve it. Here a sound approach to software engineering is a must. Otherwise, it would be impossible to collaborate and update the software with new features and bug fixes. Nevertheless, the experience in school is an important and essential beginning, even though Smith wished that it were more like the industry.

The authors of this book have all experienced, through their personal journeys, the importance of utilizing an engineering approach in providing high-quality software. Thus, we can characterize, for you, what is important in respect to software engineering.

Considering the software industry, let's put the success of Microsoft, Apple, Google, Facebook, Twitter, etc. on the side because they are so unique—relying on innovative ideas that found a vast commercial market—and programming, per se, was not the root cause of their success. In a more normal situation you will find yourself employed by a company that as part of their mission needs to develop software to support their business or to sell a product needed by potential customers. The company may be rather small or very large, and you will be part of a team. The reasons you won't be alone are many. What needs to be done is more

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than what one person can do alone. If the software product is large your team will most likely not be the only one; there will be many teams that have to work in some synchronized way to achieve the objectives of your company.

As a young student having spent most of your life at school and not yet working in the industry, you may be more interested in the technologies related to software—the computer, programming languages, operating systems, etc.—and less interested in the practicalities of developing commercial software for a particular business.

However, this is going to change with this book.

First, let us consider the importance of a team. The team has a role in the company to develop some software. To do that, they need to know what the users of the software need, or in other words they need to agree on the *requirements*. In some cases, they will receive the requirements indicating that they want software that does what another piece of software does. In these cases, the team must study the other product and do something like that product or better. In other situations, someone will just tell them what to do and be with the team while they do it. In more regulated organizations, someone (or a group of people) has written a document specifying what is believed to be some or all of the requirements. Typically, people don't specify all the requirements before starting the development, but some requirements will be input to the team, so they can start doing something to show to the future users of the product. Interacting with users on intermediary results will reveal weaknesses and tell the team what they need to do next. These discussions may imply that the team has to backtrack and redo parts of what they have done and demonstrate the new results to the users. These discussions will also tell the team what more needs to be done.

Anyway, the team will in one way or the other have to understand what requirements they should use as input to the work of their team. Understanding the requirements is normally not trivial. It may take as much time or even more as it takes to program a solution. As we just stated, you will typically have to modify them and sometimes throw away some of the requirements as well as work results before the users of the software are reasonably satisfied with what they have received.

As a newcomer to software engineering but with some background in programming, you may think that working with requirements is less rewarding and less interesting than programming. Well, it is not. There is an entire discipline (*requirements engineering*) that specifies how you dig out the requirements, how you think about them to create great user experiences supported by the software, and how you

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modify them to improve and sustain the software. There are requirements management tools to help you that are as interesting to work with as programming tools. There are many books and other publications on how to work with requirements, so there is a lot to learn as you advance in your career. Therefore, working with requirements is one of the things to do that is more than programming but part of software engineering.

Another thing to do that is more than programming is the *design* of the software. Design means structuring the code in such a way that it is easy to understand, easy to change to meet new requirements, easy to test, etc. You can describe your design by using elements of a programming language such as component, class, module, interface, message, etc. You can also use a visual language with symbols for such elements that have a direct correspondence in the programming language you are utilizing. In the latter case, you use a tool to draw diagrams with symbols representing, for instance, components with interfaces. In short, you express the design in a diagram form. The visual language can be quite sophisticated and allow you to not just express your design; for example, you can do quality controls using a visual language tool as well as testing the design to some extent. Doing design is as interesting and rewarding as programming and it is an important part of software engineering.

Apart from working with requirements and creating a design, there are many other things we need to do when we engineer software. We do extensive *testing* of the software; we *deploy* it on a computer so it can be executed and used. If the software we have developed is successful, we will *change* it for many years to come. In fact, most people developing software are engaged in changing existing software that has been developed, often many years ago. This means we need to deal with versions of existing software and if the software has been used at many places (even around the world) we often need to have different versions of the same original software at different locations in the world. Each version will change independent of the other existing versions. And, the complexity of the software product just continues to increase. The only way to deal with this complexity is to use tools specifically designed for its purpose: testing, deployment, version and configuration control, etc.

So, you see that software engineering is certainly much more than programming. While definitions of software engineering are always a subject of debate among professionals, the following neatly summarizes our view. *Software engineering is the application of a systematic, disciplined, and quantifiable approach to the development, testing, deployment, operation, and maintenance of software systems.*

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To us, "*a systematic, disciplined, and quantifiable approach*" means it is repeatable and consistent from one project to another, with continuous improvement on the way. It means it is accompanied by some form of description of the way of working and it allows us to automate more. Software engineering includes understanding what users and other stakeholders need and transforming those needs into clear requirements that can be understood by programmers. It also includes understanding the specific technologies needed to build and to test the software. It requires teams that have the social skills to work together, so each piece of the software works with other pieces to achieve the overall goal. So, software engineering encompasses the collaboration of individuals to evolve software to achieve some goal.

Programming is very rewarding since you immediately see the impact of your work. However, as you will learn during your journey, the other activities in software engineering—requirements, design, testing, etc.—are also fascinating for similar reasons. It has been more difficult, though, to teach these other activities in a systematic and generic manner. This is due to the fact that there are so many variations of these activities and there has not been a common ground for teaching them until now as presented in this book. You will find that most students who study in the software domain have an initial desire to work with programming. However, as these people become more and more experienced they gradually move into the other areas of software engineering. This is not because programming is not important. In fact, without programming there is no product to use and sell. No, it is because they find the other areas to be more challenging; also, success in these other areas requires more experience. By essentializing software engineering as presented in this book, the full scope of the discipline will be easier to grasp and to teach.

What Should You Now Be Able to Accomplish?

After studying this chapter, you should be able to:

- explain the terms *programming*, *software development*, and *software engineering*, and how they relate to each other;
- explain the difference between professional programming and hacking;
- understand how teamwork affects the dynamics of software engineering (e.g., importance of code understandability);

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- explain the importance of testing as a tool to promote safe modification of existing code;
- understand how people management blends into software engineering and why it is important to consider it;
- explain the role of requirements engineering.

In order to support your learning activities, we invite you to visit www.software-engineering-essentialized.com. There one can find additional material, exercises related to this chapter, and some questions one might encounter in an exam.

In addition to this you will find a short account of the history of software engineering in Appendix A.

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2 Software Engineering Methods and Practices

In this chapter we present how the *way of working* to develop software is organized, and to some extent what additional means are needed (e.g., notations for specifications). In particular, we

- describe the challenges in software engineering covering a wide range of aspects like how to proceed step by step, involve people, methods and practices;
- outline various key concepts of some commonly used software engineering methods created during the last four decades (i.e., waterfall methods, iterative lifecycle methods, structured methods, component methods, agile methods); and
- describe the motivation behind the initiative to create the Essence standard as a basic and extendable foundation for software engineering.

This will also take the reader briefly through the development of software engineering.

2.1 Software Engineering Challenges

From Smith's specific single-person view of software engineering, we move to take a larger worldview in this chapter and the next. We will return to Smith's journey in Chapter 4. From 2012–2014, the IEEE Spectrum published a series of blogs on IT hiccups.[1] There are all kinds of bloopers and blunders occurring in all kinds of industries, a few of which we outline here.

- According to the *New Zealand Herald*, the country's police force in February 2014 apologized for mailing over 20,000 traffic citations to the wrong drivers.

1. http://spectrum.ieee.org/riskfactor/computing/it/it-hiccups-of-the-week

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Apparently, the NZ Transport Agency, which is responsible for automatically updating drivers' details and sending them to the police force, failed to do so from October 22 to December 16, 2013. As a result, "people who had sold their vehicles during the two-month period . . . were then incorrectly ticketed for offenses incurred by the new owners or others driving the vehicles." In New Zealand, unlike the U.S., license plates generally stay on a vehicle for its life.[2]

- The *Wisconsin State Journal* reported in February 2013 that "glitches" with the University of Wisconsin's controversial payroll and benefits system had resulted in US $1.1 million in improper payments which the university would likely end up having to absorb. This was after a news report in the previous month indicated that problems with the University of Wisconsin's payroll system had resulted in $33 million in improper payments being made over the past two years.[3]

These types of highlighted problems seem to be those which we can find amusing; however they are really no laughing matter if you happen to be one of the victims. What is more surprising is that the problem with these situations is that they can be prevented, but they almost inevitably do occur.

2.2 The Rise of Software Engineering Methods and Practices

Just as we have compressed Smith's journey from a young student to a seasoned software engineer in a few paragraphs, we will attempt to compress some 50 years of software engineering into a few paragraphs. We will do that with a particular perspective in mind: what resulted in the development of a common ground in software engineering—the Essence standard. A more general description of the history is available in Appendix A.

However, the complexity of software programs did not seem to be the only root cause of the so-called "software crisis." Software endeavors and product development are not just about programming; they are also about many other things such as understanding what to program, how to plan the work, how to lead the people and getting them to communicate and collaborate effectively.

2. http://spectrum.ieee.org/riskfactor/computing/it/new-zealand-police-admits-sending-20-000-traffic-tickets-to-the-wrong-motorists

3. http://spectrum.ieee.org/riskfactor/computing/it/it-hiccups-of-the-week-university-of-wisconsin-loses-another-11-million-in-payroll-glitches

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For the purpose of this introductory discussion, we define a *method* as providing guidance *for all the things you need to do* when developing and sustaining software. For commercial products *"all the things"* are a lot. You need to work with clients and users to come up with "the what" the system is going to do for its users—the requirements. Further, you need to design, code, and test. However, you also need to set up a team and get them up to speed, they need to be assigned work, and they need a way of working.

These things are in themselves "mini-methods" or what many people today would call *practices*. There are *solution*-related "practices," such as work with requirements, work with code, and conduct testing. There are *endeavor*-related practices, such as setting up a collaborative team and an efficient endeavor as well as improving capability of the people and collecting metrics. There are of course *customer*-related practices, such as making sure that what is built is what the customers really want.

The interesting discovery we made more than a decade ago was that even if the number of methods in the world was huge, it seemed that all these methods were just compositions of a much smaller collection of practices, maybe a few hundred of such practices in total. Practices are what we call *reusable* because they can be used over and over again to build different methods.

To understand how we as a software engineering community have improved our knowledge in software engineering, we provide a description of historical developments. Our purpose with this brief history is to make it easier for you to understand why Essence was developed.

2.2.1 There Are Lifecycles

From the ad hoc approach used in the early years of computing came the *waterfall* method around the 1960s; actually, it was not just one single method—it was a whole class of methods. The waterfall methods describe a software engineering project as going through a number of phases such as Requirements, Design, Implementation (Coding), and Verification (i.e., testing and bug-fixing) (see Figure 2.1).

While the waterfall methods helped to bring some discipline to software engineering, many people tried to follow the model literally, which caused serious problems especially on large complex efforts. This was because software engineering is not as simple as this linear representation indicates.

A way to describe the waterfall methods is this: What do you have once you think you have completed the requirements? Something written on "paper." (You may have used a tool and created an electronic version of the "paper," but the point is that it is just text and pictures.) But since it has not been used, do you know for sure

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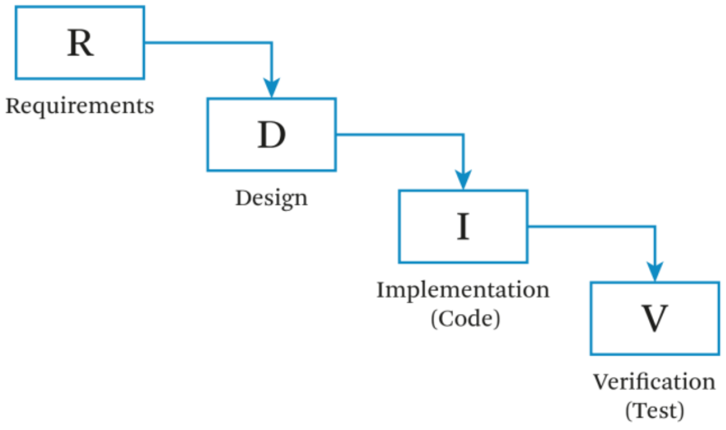

Figure 2.1 Waterfall lifecycle.

at this point if they are the right requirements? No, you don't. As soon as people start to use the product being developed based on your requirements, they almost always want to change it.

Similarly, what do you have after you have completed your design? More "paper" of what you think needs to be programmed? But are you certain that it is what your customer really intended? No, you are not. However, you can easily claim you are on schedule because you just write less and with less quality.

Even after you have programmed according to the design, you still don't know for sure. However, all of the activities you have conducted don't provide proof that what you did is correct.

Now you may feel you have done 80%. The only thing you have left is to test. At this point the endeavor almost always falls apart, because what you have to test is just too big to deal with as one piece of work. It is the code coming from all the requirements. You thought you had 20% left but now you feel you may have 80% left. This is a common well-known problem with waterfall methods.

There are some lessons learned. Believing you can specify all requirements upfront is just a myth in the vast majority of situations today. This lesson learned has led to the popularity of more iterative lifecycle methods. Iterating means you can specify some requirements and you can build something meeting these requirements, but as soon as you start to use what you have built you will know how to make it a bit better. Then you can specify some more requirements and build, and test these until you have something that you feel can be released. But to gain confidence you need to involve your users in each *iteration* to make sure what you have

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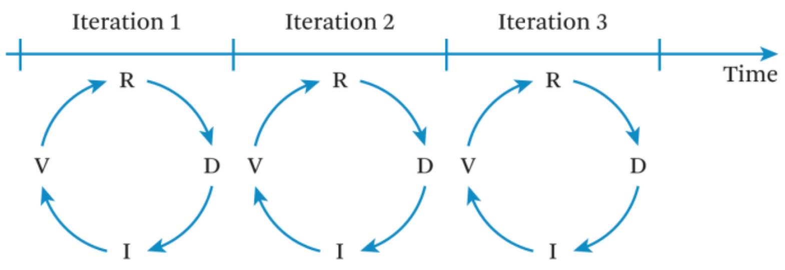

Figure 2.2 Iterative lifecycle.

provides value. These lessons gave rise at the end of the 1980s to a new lifecycle approach called iterative development, a lifecycle adopted by the agile paradigm now in fashion (see Figure 2.2).

New practices came into fashion. The old project management practices fell out of fashion and practices relying on the iterative metaphor became popular. The most prominent practice was Scrum, which started to become popular at the end of the 1990s and still is very popular. We will discuss this more deeply in Part III of the book.

2.2.2 There Are Technical Practices

Since the early days of software development, we have struggled with how to do the right things in our projects. Originally, we struggled with programming because writing code was what we obviously had to do. The other things we needed to do were ad hoc. We had no real guidelines for how to do requirements, testing, configuration management, project management, and many of these other important things.

Later new trends became popular.

2.2.2.1 The Structured Methods Era

In the late 1960s to mid-1980s, the most popular methods separated the software to be developed into the *functions* to be executed and the *data* that the functions would operate upon: the functions living in a program store and the data living in a data store. These methods were not farfetched because computers at that time had a program store, for the functions translated to code, and a data store. We will just mention two of the most popular methods at that time: SADT (Structured Analysis and Design Technique) and SA/SD (Structured Analysis/Structured Design). As a student, you really don’t need to learn anything more about these methods. They

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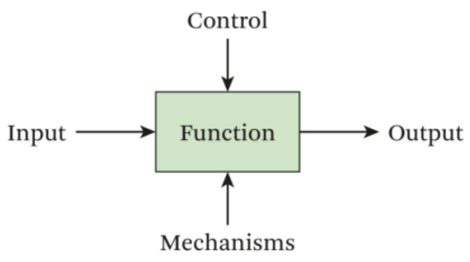

Figure 2.3 SADT basis element.

were used for all kinds of software engineering. They were not the only methods in existence. There were a large number of published methods available and around each method there were people strongly defending it. It was at this time in the history of software engineering that the *methods war* started. And, unfortunately, it has not yet finished!

Every method brought with it a large number of practices such as requirements, design, test, defect management, and the list goes on.

Each had its own blueprint notation or diagrams to describe the software from different viewpoints and with different levels of abstraction (for example, see Figure 2.3 on SADT). Tools were built to help people use the notation and to keep track of what they were doing. Some of these practices and tools were quite sophisticated. The value of these approaches was, of course, that what was designed was close to the realization—to the machine: you wrote the program separate from the way you designed your data. The problems were that programs and data are very interconnected and many programs could access and change the same data. Although many successful systems were developed applying this approach, there were far many more failures. The systems were hard to develop and even harder to change safely, and that became the Achilles' heel for this generation of methods.

2.2.2.2 The Component Methods Era

The next method paradigm shift[4] came in early 1980 and had its high season until the beginning of the 2000s.

In simple terms, a software system was no longer seen as having two major parts: functions and data. Instead, a system was a set of interacting elements—

4. Wikipedia: "A paradigm shift, as identified by American physicist and philosopher Thomas Kuhn, is a fundamental change in the basic concepts and experimental practices of a scientific discipline."

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Sidebar 2.1 Paradigm Shift in Detail

In more detail, this paradigm shift was inspired by a new programming metaphor—*object-oriented* programming—and the trigger was the new programming language Smalltalk. However, the key ideas behind Smalltalk were derived from an earlier programming language, Simula 67, that was released in 1967. Smalltalk and Simula 67 were fundamentally different from previous generations of programming languages in that the whole software system was a set of classes embracing its own data, instead of programs (subroutines, procedures, etc.) addressing data types in some data store. Execution of the system was carried out through the creation of objects using the classes as templates, and these objects interacted with one another through exchanging messages. This was in sharp contrast to the previous model in which a process was created when the system was triggered, and this process executed the code line by line, accessing and manipulating the concrete data in the data store. A decade later, around 1990, a complement to the idea of objects received widespread acceptance inspired, in particular, by Microsoft. We got *components*.

components (see also Sidebar 2.1). Each component had an interface connecting it with other components, and over this interface messages were communicated. Systems were developed by breaking them down into components, which collaborated with one another to provide for implementation of the requirements of the system. What was inside a component was less important as long as it provided the interfaces needed to its surrounding components. Inside a component could be program and data, or classes and objects, scripts, or old code (often called legacy code) developed many years ago. Components are still the dominating metaphor behind most modern methods. An interesting development of components that has become very popular is microservices, which we will discuss in Part III.

With components, a completely new family of methods evolved. The old methods with their practices were considered to be out of fashion and were discarded. What started to evolve were in many cases similar practices with some significant differences but with new terminology. In the early 1990s, about 30 different component methods were published. They had a lot in common, but it was almost impossible to find the commonalities since each method author created his/her own terminology.

In the second half of the 1990s, OMG (a standards body called Object Management Group) felt that it was time to at least standardize how to represent software drawings, namely notations used to develop software. This led to a task force being created to drive the development of a new standard. The work resulted in the

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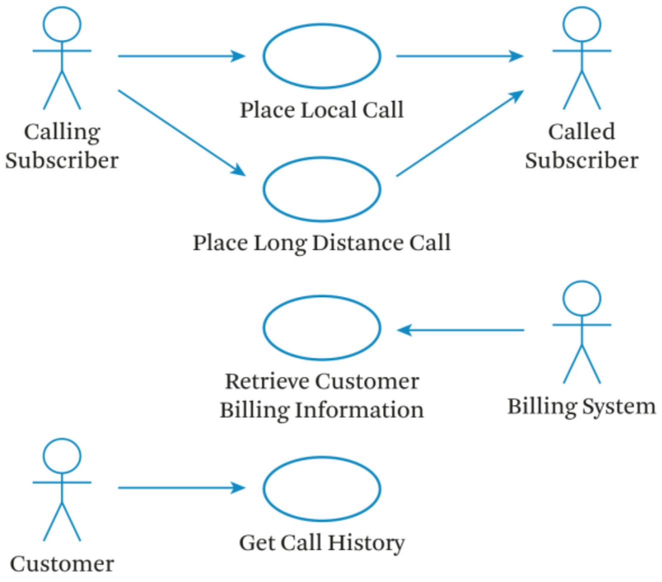

Figure 2.4 A diagram (in fact a Use-Case diagram) from the Unified Modeling Language standard.

Unified Modeling Language (UML; see Figure 2.4), which will be used later in the book. This development basically killed all methods other than the Unified Process (marketed under the name Rational Unified Process (RUP)). The Unified Process dominated the software engineering world around the year 2000. Again, a sad step, because many of the other methods had very interesting and valuable practices that could have been made available in addition to some of the Unified Process practices. However, the Unified Process became in fashion and everything else was considered out of fashion and more or less thrown out.

Over the years, many more technical practices other than the ones supported by the 30 component methods arrived. More advanced architectural practices or sets of practices, e.g., for enterprise architecture (EA), service-oriented architecture (SOA), product-line architecture (PLA), and recently architecture practices for big data, the cloud, mobile internet, and the internet of things (IoT) evolved. At the moment, it is useful to see these practices as pointers to areas of software engineering interest at a high level of abstractio: suffice it to say that EA was about large information systems for, e.g., the finance industry; SOA was organizing the software as a set of possibly optional service packages; and PLA was the counterpart of EA but for product companies, e.g., in the telecom or defense industry. More important is to know that again new methodologies grew up as mushrooms around each one

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of these technology trends. With each new such trend method authors started over again and reinvented the wheel. Instead of "standing on the shoulders of giants,"[5] they preferred to stand on another author's toes. They redefined already adopted terminology and the methods war just continued.

2.2.2.3 The Agile Methods Era

The agile movement—often referred to just as *agile*—is now the most popular trend embraced by the whole world. Throughout the history of software engineering, experts have always been trying to improve the way software is being developed. The goal has been to compress timescales to meet the ever-changing business demands and realities. If agile were to have a starting date, one can pinpoint it to the time when 17 renowned industry experts came together and penned the words of the agile manifesto. We will present the manifesto in Part IV and how Essence contributes to agile. But for now, it suffices to say that agile involves a set of technical and people-related practices. Most important is that agile emphasizes an innovative mindset such that the agile movement continuously evolves its practices.

Agile has evolved the technical practices utilized with components. However, its success did not come from introducing many new technical practices, even if some new practices, such as continuous integration, backlog-driven development, and refactoring, became popular with agile. Continuous integration suggests that developers several times daily integrate their new code with the existing code base and verify it. Backlog-driven development means that the team keeps a backlog of requirement items to work with in coming iterations. We will discuss this practice in more detail when we discuss Scrum in Part III. Refactoring is to continuously improve existing code iteration by iteration.

Agile rather simplified what was already in use to assist working in an iterative style and providing releasable software over many smaller iterations, or sprints as Scrum calls them.

2.2.3 There Are People Practices

As strange as it may sound, the methods we employed in the early days did not pay much attention to the human factors. Everyone understood of course that software was developed by people, but very few books or papers were written about how to get people motivated and empowered in developing great software. The most

5. From Wikipedia: "The metaphor of dwarfs standing on the shoulders of giants . . . expresses the meaning of 'discovering truth by building on previous discoveries'."

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successful method books were quite silent on the topic. It was basically assumed that in one way or the other this was the task of management.

However, this assumption changed dramatically with agile methods. Before, there was a high reliance on tools so that code could be automatically generated from design documents such as UML diagrams. Accordingly, the role of programmers was downgraded, and other roles were more prestigious, such as project managers, analysts, and architects. With agile methods programming became reevaluated as a creative job. The programmers, the people who eventually created working software, were "promoted" and coding became again a prestigious task.

With agile many new practices evolved, for instance self-organizing teams, pair programming, and daily standups.

A self-organizing team includes members who are more generalists than specialists—most know how to code even if some are experts. It is like a soccer team—everyone knows how to kick the ball even if some are better at scoring goals and someone else is better at keeping the ball out of the goal.

Pair programming means that two programmers are working side-by-side developing the same piece of code. It is expected that the code quality is improved and that the total cost will be reduced. Usually one of the two, is more senior than the other, so this is also a way to improve team competency.

Daily standup is a practice intended to reduce impediments that team members have, as well as to retain motivation. Every morning the team meets for 15 min to go through each member's situation: what he/she has done and what he/she will be doing. Any impediments are brought up but not addressed during the meeting. The issues will be discussed in separate meetings. This practice is part of the Scrum practice discussed in Part III.

Given the impact agile has had on the empowerment of programmers, it is easy to understand that agile has become very popular. Moreover, given the positive impact agile has had on our development of software, there is no doubt it has deserved to become the latest paradigm.

2.2.4 Consequences

There is a methods war going on out there. It started 50 years ago, and it still goes on. Jokingly, we can call it the Fifty Years' War, and there is still no truce. In fact, there are no signs that this will stop by itself.

- With every major paradigm shift such as the shift from structured methods to component methods and from the latter to the agile methods, basically the industry throws out all they know about software engineering and starts

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all over with new terminology with little relation to the old. Old practices are viewed as irrelevant and new practices are hyped. To make this transition from the old to the new is extremely costly to the software industry in the form of training, coaching, and change of tooling.

- With every major technical innovation, for instance cloud computing, requiring a new set of practices, the method authors also "reinvent the wheel." Although the costs are not as huge as in the previous point, since some of the changes are not fundamental across everything we do (it is no paradigm shift) and thus the impact is limited to, for instance, cloud development, there is still foolish waste.
- Within every software engineering trend there are many competing methods. For instance, back as early as 1990 there were about 30 competing object-oriented methods. When this book was written, there were about 10 competing methods on scaling agile to large organizations; some of the most famous ones are Scaled Agile Framework (SAFe), Disciplined Agile Delivery (DAD), Large Scale Scrum (LeSS), and Scaled Professional Scrum (SPS). They typically include some basic widely used practices such as Scrum, user stories or alternatively use cases, and continuous integration, but the method author has "improved" them—sarcastically stated. There is reuse of ideas, but not reuse of original text, so the original inventor of the practice feels he or she has been robbed of his/her work; there is no collaboration between method authors, but instead they are "at war" as competing brands.

  Within these famous methods, there are some often useful practices that are specific for each one. The problem is that all these methods are monolithic, not modular, which means that you cannot easily mix and match practices from different methods. If you select one, you are more or less stuck with it. This is not what teams want, and certainly not their companies. This is, of course, what most method authors whose method is selected like, even if it was never what they intended.

Typically, every recognized method has a founding parent, sometimes more than one parent. If successful, this parent is raised to guru status. The guru more or less dictates what goes into his/her method. Thus, once you have adopted a method, you get the feeling you are in a *method prison* controlled by the guru of that method. Ivar Jacobson, together with Philippe Kruchten, was once such a guru governing the Unified Process prison. Jacobson realized that this was "the craziest thing in the world," a situation unworthy in any industry and in particular in such a huge industry as the software industry. To eradicate such unnecessary method wars and

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method prisons, the SEMAT (Software Engineering Method and Theory) initiative was founded.

2.3 The SEMAT Initiative

As of the writing of this book there are about 20 million software developers[6] in the world and the number is growing year by year. It can be guesstimated that there are over 100,000 different methods to develop software, since basically every team has developed their own way of working even if they didn't describe it explicitly.

Over time, the number of methods is growing much faster than the number of reusable practices. There is no problem with this. In fact, this is what we want to happen, because we want every team or organization to be able to set up its own method. The problem is that until now we have not had any means to really do that. Until now, creating your own method has invited the method author(s) to reinvent everything they liked to change. This has occurred because we haven't had a solid common ground that we all agreed upon to express our ideas. We didn't have a common vocabulary to communicate with one another, and we didn't have a solid set of reusable practices from which we could start creating our own method.

In 2009, several leaders of the software engineering community came together, initiated by Ivar Jacobson, to discuss the future of software engineering. Through that, the SEMAT (Software Engineering And Theory) initiative commenced with two other leaders founding it: Bertrand Mayer and Richard Soley.

The SEMAT call for action in 2009 read as follows.

> Software engineering is gravely hampered today by immature practices. Specific problems include:
>
> - The prevalence of fads more typical of fashion industry than of an engineering discipline.
> - The lack of a sound, widely accepted theoretical basis.
> - The huge number of methods and method variants, with differences little understood and artificially magnified.
> - The lack of credible experimental evaluation and validation.
> - The split between industry practice and academic research.

6. https://www.infoq.com/news/2014/01/IDC-software-developers

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We support a process to re-found software engineering based on a solid theory, proven principles, and best practices that:

- Include a kernel of widely agreed elements, extensible for specific uses
- Address both technology and people issues
- Are supported by industry, academia, researchers and users
- Support extension in the face of changing requirements and technology.

This call for action was signed by around 40 thought leaders in the world coming from most areas of software engineering and computer science; 20 companies and about 20 universities have signed it, and more than 2,000 individuals have supported it. You should see the "specific problems" identified earlier as evidence that the software world has severe problems. When it comes to the solution "to re-found software engineering" the keywords here are "a kernel of widely agreed elements," which is what this book has as a focus.

It was no easy task to get professionals around the world to agree on what software engineering is about, let alone how to do it. It led, of course, to significant controversy. However, the supporters of SEMAT persevered. Never mind that the world is getting more complex, and there is no single answer, but there ought to be some common ground—a kernel.

2.4 Essence: The OMG Standard

After several years of hard work, the underlying language and kernel of software engineering was accepted in June 2014 as a standard by the OMG and it was given the name Essence. As is evident from the call for action, the SEMAT leaders realized already at the very start that a common ground of software engineering (a kernel) needed to be widely accepted. In 2011, after having worked two years together and having reached part of a proposal for a common ground, we evaluated where we were and understood that the best way to get this common ground widely accepted was to get it established as a formal standard from an accredited standards body. The choice fell on OMG. However, it took three more years to get it through the process of standardization. Based upon experience from the users of Essence, it continues to be improved by OMG through a task force assigned to this work.

In the remainder of this part of the book, we will introduce Essence, the key concepts and principles behind Essence, and the value and use cases of Essence.

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This material is definitely useful for all students and professionals alike. Readers interested in learning more, please see Jacobson et al. [2012, 2013a, 2013b], and Ng [2014].

What Should You Now Be Able to Accomplish?

After studying this chapter, you should be able to:

- explain the meaning of a method (as providing guidance for all the things you need to do when developing and sustaining software);
- explain the meaning of a practice and its types (i.e., solution-related practices, endeavor-related practices, customer-related practices);
- explain the meaning of waterfall methods and their role in the history of software engineering;
- explain the iterative lifecycle methods, structured methods, component methods, and agile methods, as well as their characteristics;
- give examples of some practices (e.g., self-organizing teams, pair programming, and daily standups as examples of agile practices);
- explain the "method prison" issue discussed in the chapter; and
- explain the SEMAT initiative and the motivation behind the Essence standard.

Again we point to additional reading, exercises, and further material at www.software-engineering-essentialized.com.

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3 Essence in a Nutshell

In this chapter we present key ideas resulting in Essence as a common ground for all software engineering methods. Basic concepts of Essence, the notion of a *method* and the architecture of Essence are introduced. In particular, this chapter introduces and explains

- the key ideas resulting in Essence and why they are important for software engineering;
- the concept of composition as a way to combine practices to form a method to guide a development endeavor;
- the common ground Essence as consisting of a language and a kernel of essential elements;
- the concepts of practices and methods built of top of Essence forming a method architecture; and
- the concept of cards as a means to give the abstract elements of Essence an attractive and tangible user experience.

This chapter shows that the main idea behind Essence is to focus on the most important things to think about when developing software (focus on the essentials only).

Essence became a standard in 2014 as a response to "the craziest thing in the world" presented in Chapters 1 and 2.

In this chapter, we will present some key ideas used as input when designing Essence. We will also separately motivate each idea and describe how it has been realized with Essence.

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3.1 The Ideas

Essence relies on the following insights.

- Methods are compositions of practices.
    - There are a huge number of methods (guesstimated to be $> 100{,}000$) in the world, some of which are recognized and have a large user base.
    - There are only a few hundred reusable practices in the world. With n practices the number of theoretically possible combinations of these practices can quickly grow very large.
- There is a common ground, or a kernel, shared among all these methods and practices.
- Focus on the essentials is needed when providing guidelines for a method or practice.
- Providing an engaging user experience is possible when teaching and learning methods and practices.

3.2 Methods Are Compositions of Practices

As explained in Chapter 2, a method is created with the intention to guide the software development team(s) through everything they need to do during the development process: that is, giving them all the practices they need. A practice is like a mini-method in that it guides a team in how to carry out one particular thing in their work. For instance, "requirements management" is a potential practice dealing with what a software system should do. It is obviously not all you need to do when you develop software; you need many other such practices, for instance, "design, implement, and test," "organize your team," "perform project management," etc. For small endeavors, it is not uncommon that you need a dozen such mini-methods/practices.

Because a method is attempting to give complete guidance for the work, it relies on a composition of practices. This is an operation merging two or more practices to form the method. Such a composition operation has to be defined mathematically in order to be unambiguous and precise. It has to be specified by a method expert with the objective to resolve potential overlaps and conflicts among the practices, if there are any. Usually most practices can be composed easily by setting them side

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by side because there are no overlaps and conflicts, but in some cases, these have to be taken care of.

This is because, while practices are separate, they are not independent. They are not like components that have interfaces over which communication/interoperation will happen. They also share elements, so let us briefly look at what these might be. Inside a practice are, for instance, guidelines for activities that a user (e.g., a developer) is supposed to perform, and guidelines for work products (e.g., components) that a user is expected to produce. Although two practices may share the same work product, they contribute separate guidelines to this work product, and composing these two practices, resolving potential overlaps and conflicts, will require that you specify how the contributions must be combined in a meaningful and constructive way.

However, not just methods are compositions, but also practices can be compositions of smaller practices. Scrum, for instance, can be seen as a composition of three smaller practices: Daily Standup, Backlog-Driven Development, and Retrospective. (We will discuss these later when we come to Scrum in Part III.)

We will come back later to compositions when we have more details about practices in our knowledge bag. (If you want to have a peek into more on compositions now, take a look at Chapter 19.)

What eventually becomes a method or a practice is just a practical decision. To reiterate, a method is closer to the complete guidance you need whereas a practice (composed or not) is just one aspect (or several) of what you need to guide the team(s) to deal with all the "things" they need to deal with when developing software. An individual can create one or a few practices based on experience, but a method is always too big to be created by one individual without "borrowing" practices from others. We say "borrowing" within quotes, because it is an act without consent of the originator. Practices are successful because of the knowledge they provide, whereas methods are usually branded (like RUP, SAFe, DAD, Nexus, Less) and success is more about great marketing than about knowledge being provided.

When we say that a practice guides a team, we mean it is described one way or another to indicate what to do. How explicit a practice should be, i.e., how detailed the descriptions should be, depends on two factors: capabilities and background.

Capability. Capability refers to team members' ability, based upon the knowledge they already have, to figure things out for themselves. Team members with high skill and capability need only a few reminders and examples to

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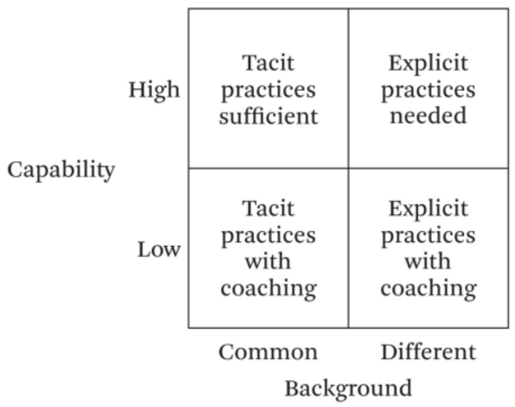
High
Low
Capability
Tacit practices sufficient
Explicit practices needed
Tacit practices with coaching
Explicit practices with coaching
Common
Different
Background

Figure 3.1 How explicit practices depend on capability and background.

get going. Others may need training and coaching to learn how to apply a practice effectively.

Background. If the team has worked together using a practice in the past or have gone through the same training, then they have a shared background. In this case, practices can be tacit. On the other hand, if team members have been using different practices, e.g., some have been using traditional requirements specifications while others have been using user story (a more modern way of dealing with requirements), then they have different backgrounds. In this case, practices should be described to avoid miscommunication.

How these two factors interact and influence the form that your practices should take is summarized in Figure 3.1.

As an example, in the case where a team's requirements challenges relate to different backgrounds and members do not know that much about requirements collaboration techniques, the team needs explicit practices and some coaching which a more experienced team member can provide out of the box. Additional factors to be considered, contributing to the need for practices, include the size of the team and how its members are geographically distributed.

3.3 There Is a Common Ground

Using a common ground as a basis for presenting guidelines for all practices will make it easier to teach, learn, use, and modify practices and easier to compare practices described using the same common ground.

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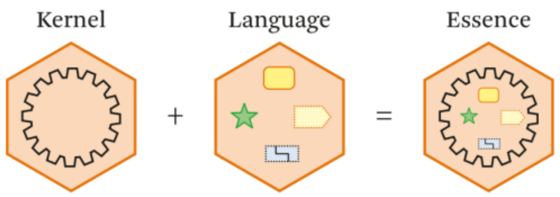

Figure 3.2 Essence and its parts.

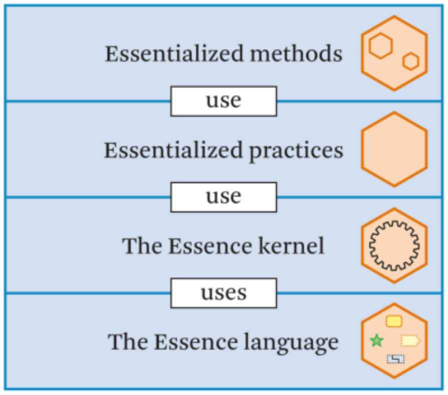

Figure 3.3 Essence method architecture.

Figure 3.2 illustrates Essence as this common ground, providing both a language and a kernel of software engineering.

The Essence language is very simple, intuitive, and practical, as we will show later in this section.

As previously described, it was left to the software engineering community to contribute practices, which can then be composed to form methods. Figure 3.3 depicts the relationships between methods composed using practices, which are described using the Essence kernel and the Essence language. As you can see in Figure 3.3, the notation used in the Essence language for practices is the hexagon, and for methods it is the hexagon enclosing two minor hexagons.

The practices are *essentialized*, meaning they are described using Essence—the Essence kernel and the Essence language. Consequently, the methods we will describe are also *essentialized*. In Part III you will see many examples of essentialized practices.

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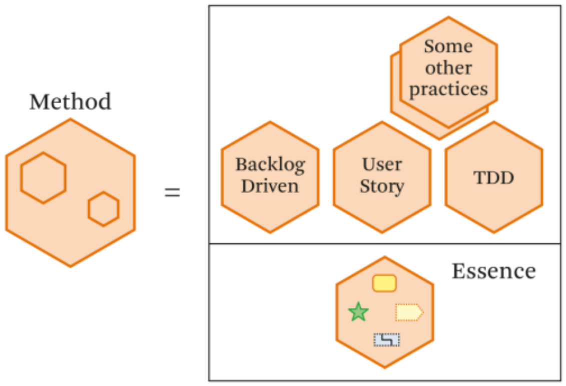

Figure 3.4 A method is a composition of practices on top of the kernel.

Essentializing not only means that the method/practice is described using Essence; it also focuses the description of the method/practice on what is essential. It doesn't mean changing the intent of the practice or the method. This provides significant value. We as a community can create libraries of practices coming from many different methods. Teams can mix and match practices from many methods to obtain a method they want. If you have an idea for a new practice, you can just focus on essentializing that practice and add it to a practice library for others to select; you don't need to "reinvent the wheel" to create your own method (see, e.g., Figure 3.4. This liberates that practice from monolithic methods, and it will open up the method prisons and let companies and teams get out to an open world.

As mentioned earlier, a team usually faces a number of challenges and will need the guidance of several practices. Starting with the kernel, a team can select a number of practices and support tools to make up its way-of-working. The set of practices that they select for their way-of-working is their method.

When learning a new practice or method, perhaps about use cases, or user stories, it is sometimes difficult to see how it will fit with your current way-of-working. By basing the practices on a common ground, you can easily relate new practices to what you already have. You learn the kernel once and then you just focus on what is different with each new practice.

Even if there are many different methods (every team or at the least every organization has one), they are not as different as it may seem. Examples of common practices are user story, test-driven development (TD), and backlog driven development. These terms may not mean much to you now, but in Part III we will give meaning to them. Right now, this combination serves just as an example of the relationship between a method and its practices.

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Sidebar 3.1 How Much Does a Developer Need to Know About Methods?

You may be asking yourself at this point, do I really need to care about all of this method theory? Remember, a method is a description of the team's way of working and it provides help and guidance to the team as they perform their tasks. What the kernel does is help you structure what you do in a way that supports incremental evolution of the software system. In other words, it puts you in control of the way you work and provides the mechanism to change it.

The idea of describing practices on top of the kernel is a key theme of this book. A further discussion of how they are formed this way is found in Part III (see also Sidebar 3.1).

3.4 Focus on the Essentials

Our experience is that developers rarely have the time and interest to read detailed methods or practices. Starting to learn the essentials gets teams ready to start working significantly earlier than if they first have to learn "all" there is to say about the subject.

These essentials are usually just a small fraction of what an expert knows about a subject—we suggest 5%—but with the essentials you can participate in conversations about your work without having all the details. It helps to grow T-shaped people—people who have expertise in a particular field, but also broad knowledge across other fields. Such people are what the industry needs as work becomes more multi-disciplinary. Once you have learned the essentials it is relatively straightforward to find out more by yourself from different sources.

Some teams and organizations need more than the essentials, so different levels of details must be made optional.

3.5 Providing an Engaging User Experience

Many books have been written to teach software engineering. Some people interested in learning about ideas and trends in this space read these books, but the vast majority of software development practitioners don't—not even if they have bought the books. Thus, textbooks are not the best way to teach practices to practitioners. Modern method-authors have taken a different approach by presenting their methods as a navigable website.

Essence has taken a different approach by providing a hands-on, tangible user experience focused on supporting software professionals as they carry out their work. For example, the kernel can be accessed (and actually touched) through the

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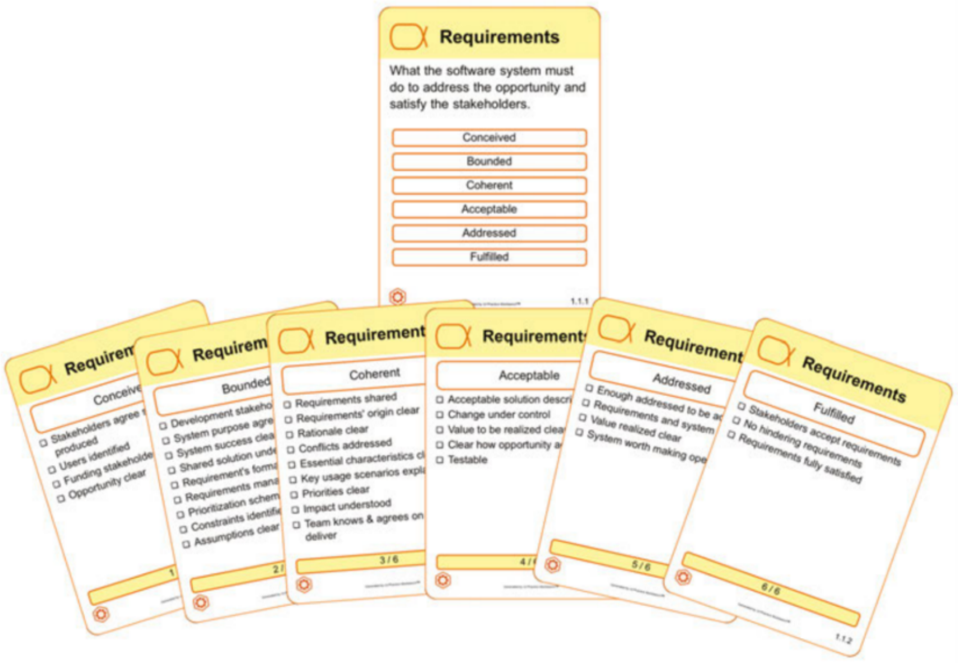
Requirements
What the software system must do to address the opportunity and satisfy the stakeholders.
Conceived
Bounded
Coherent
Acceptable
Addressed
Fulfilled
Requirements shared
Requirements' origin clear
Rationale clear
Conflicts addressed
Priorities clear
Impact understood
Change under control
Testable
Stakeholders accept requirements
No hindering requirements
Requirements fully satisfied

Figure 3.5 Cards make the kernel and practices tangible.

use of cards (see Figure 3.5). The cards provide concise reminders and cues for team members as they go about their daily tasks. By providing practical check-lists and prompts, as opposed to conceptual discussions, the kernel becomes something the team uses on a daily basis. This is a fundamental difference from traditional approaches, which tend to emphasize method description over method use and tend to be consulted only by people new to the team.

Cards have proven to be a lightweight and practical way to remember, but also to use in practice in a team. They make the kernel and the practices easy to digest and use. For this reason, throughout the book we will use cards to present elements in the kernel and in practices.

What Should You Now Be Able to Accomplish?

After studying this chapter, you should be able to

- name the key elements of Essence;
- distinguish between a practice and a method (give some examples of both);

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- explain the concept of composition as a key technique to build methods using practices (and to support extensibility in Essence);
- explain the concept of tacit vs. explicit practices;
- explain the role of capability and background in deciding how explicit a practice should be; and
- explain the layered architecture of Essence and its elements.

Again, we point to additional reading, exercises, and further material at www.software-engineering-essentialized.com.

Given that the reader is now equipped with ability to distinguish essential (i.e., the important) steps/aspects/decisions from those of minor importance, more knowledge can now be gained by proceeding in a given project and by working on the project with other people/stakeholders involved.

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4 Identifying the Key Elements of Software Engineering

The goal of this chapter is to present the key elements of the development endeavor, which later become "alphas," the building blocks of Essence—the things we work with when developing software. In this chapter, we discuss

- the key elements within software engineering that deliver value to the customer;
- the key elements in software engineering that are related to the targeted solution and development endeavor; and
- the role and importance of different stakeholders, requirements, and team composition.

This knowledge will help us to lay out a model of software engineering with areas of concern and key elements, which will create the basis for our understanding of Essence. To understand this model in practical application, we now rejoin Smith in his journey into software development.

4.1 Getting to the Basics

After Smith had been working in the software industry for several years, he had his fair share of ups and downs. He wished there were more ups than downs. Without a doubt, software engineering is a creative process, but Smith had come to recognize that there are some fundamental basics—some things to be mindful of, to avoid making unnecessary mistakes.

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Smith's colleagues also recognized that, but they had difficulty articulating these fundamentals due to their different backgrounds, experience, and, consequently, the different terms they used. It seemed that every time a new team was formed, members had to go through a "storming and norming" process to iron out these terms before starting to deal with the challenges.

If you have been in the software industry for some time, you can empathize with Smith. For students new to software engineering, we want you to appreciate the complexities of a software development endeavor as you read this chapter and compare that against the complexities of your class, or of project assignments that you have worked on.

Essence was developed to help people like Smith and companies like TravelEssence who rely heavily on software to run their business. What the contributors to Essence did was to lay down the foundation of software engineering for folks like Smith and yourself to cut short this startup period and ensure health and speed as your software development endeavors progress. The term health is discussed and defined later on for the area of software development. See, for example, Chapter 11 for a more detailed discussion.

Let's begin with some commonly used terms found in software engineering, which we will briefly introduce in *italics*. Regardless of size and complexity, all software development endeavors involve the following facets (see Figure 4.1):

- There are *customers* with needs to be met.
    - Someone has a problem or *opportunity* to address.
    - There are *stakeholders* who use and/or benefit from the solution produced, and some of these will fund the endeavor.
- There is a *solution* to be delivered.
    - There are certain *requirements* to be met.
    - A *software system* of one form or another will be developed.
- There is an *endeavor* to be undertaken.
    - The *work* must be initiated.
    - An empowered *team* of competent people must be formed, with an appropriate *way of working*.

These terms map out what software engineering is about. When something goes wrong, it is normally an issue with one or more of these facets. The way we handle these issues has a direct impact on the success or failure of the endeavor. We will

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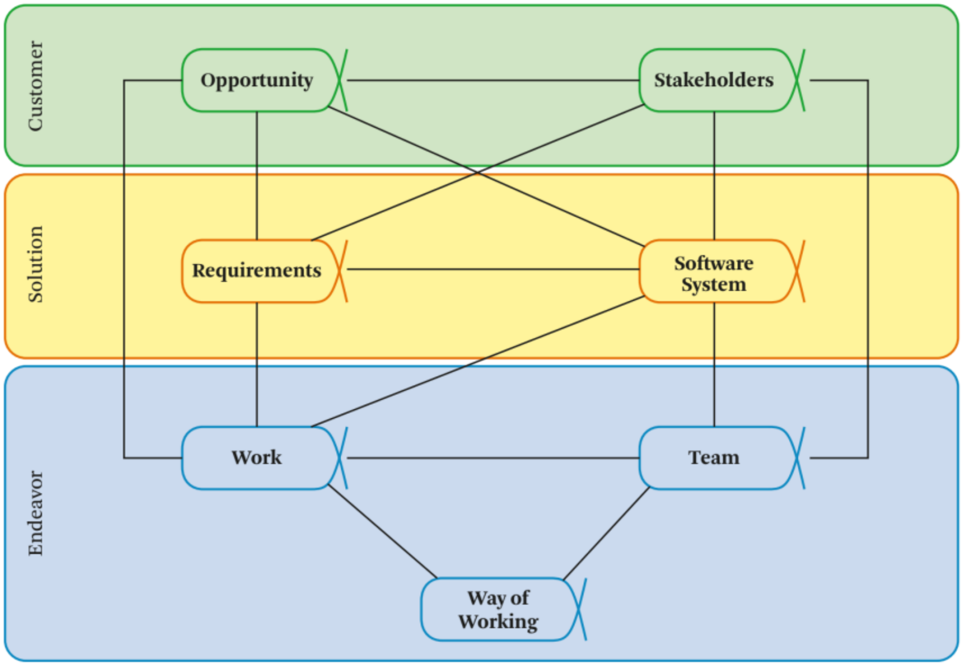

Figure 4.1 The things involved in all development endeavors.

now look at each of these facets in turn. Later, in Chapter 6, we will once more discuss issues and their relationships.

4.2 Software Engineering Is about Delivering Value to Customers

First, software engineering is about delivering value to customers. This value can be in improvements to existing capabilities or in providing new capabilities that are needed by the customer. (In our TravelEssence mode, customers are the users. They can be travelers or travel agents who make reservations on behalf of actual travelers.) Different customers would have different needs. If the endeavor does not deliver value, then it is a waste of time and money. As the saying goes, life is too short to build something that nobody wants!

4.2.1 Opportunity

Every endeavor is an opportunity for success or failure. It is therefore very important to understand what the opportunity is about. Perhaps you have heard of Airbnb. Airbnb started out in 2008 with two men, Brian Chesky and Joe Gebbia, who were

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struggling to pay rent. They came up with the idea of renting out three airbeds on their living-room floor and providing their guests with breakfast. It turned out that during that time, there was an event going on in their city and many participants weren't able to book accommodations. Brian and Joe realized they were onto something. To cut the story short, Airbnb became a 1.3 billion USD business in 2016.

However, not all businesses grow and are successful like that. In fact, far more companies do not make it, and miss many opportunities. In fact, there has been a 90% failure rate for startups.[1] Many successful companies become failures due to missed opportunities. Thus, understanding opportunities is critical.

An opportunity is a chance to do something, including fixing an existing problem. In our context, an opportunity involves building or enhancing software to meet a need. Regardless of what the opportunity is, it can either succeed or fail. It can deliver real value, or it could be something that nobody wants.

As an example, our TravelEssence model revealed that customers like to engage travel staff because of the recommendations that the staff provides. The opportunity here is that if TravelEssence can provide recommendations online through a software solution, it can provide better service to customers, thereby shortening the time customers need to make a purchase decision. Of course, whether this opportunity is truly viable depends on many factors.

Thus, when working with an opportunity it is important to continuously evaluate the viability of the opportunity as it gets implemented.

- When the opportunity is first conceived, some due diligence is necessary to determine if it truly addresses a real need or a real new idea that customers are willing to pay money for.
- It would likely be the case that different solution options are available to address the opportunity, and some difficult choices will have to be made.
- When the solution goes live, it normally takes some time before the benefits become visible to customers.

4.2.2 Stakeholders

For opportunities to be taken up, there must be some people involved in the decision. The name we have for those individuals, organizations, or groups is *stakeholders*. Stakeholders who have some interest or concern in the system being developed are known as external stakeholders; those interested in the development

1. https://www.forbes.com/sites/neilpatel/2015/01/16/90-of-startups-will-fail-heres-what-you-need-to-know-about-the-10/#43f76e846679

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endeavor itself are called internal stakeholders. In our TravelEssence case, internal stakeholders include a development team assembled to develop the new services for travelers, along with key managers in the organization who need to agree to the new venture. Examples of external stakeholders being affected by the system include a manager in our TravelEssence organization who needs to agree to fund the new software effort, or a traveler who might benefit by using the new services.

One of the biggest challenges in a development endeavor is getting stakeholders to agree. Before that can occur, they must first be involved in some way. The worst thing that could happen is that when all is said and done, someone says, "This is not what we want." This happens too often.

Thus, it is really important early in the endeavor to:

- understand who the stakeholders are and what their concerns are;
- ensure that they are adequately represented and involved in the process; and
- ensure that they are satisfied with the evolving solution.

4.3 Software Engineering Delivers Value through a Solution

What sets a software development endeavor apart from other endeavors is that the *solution* that addresses the opportunity is via a good piece of software. Nobody wants a poor-quality product. Customers' needs are ever evolving, so the solution needs to evolve as well, and for that to happen it has to be extensible. This extensibility applies to both the *requirements* of the solution and the *software system* that realizes the requirements.

In TravelEssence, the requirements for the solution cover different usage scenarios for different kinds of customers (e.g., new travelers, frequent travelers, corporate travelers, agents, etc.). The software system involves a mix of mobile applications and a cloud-based backend.

4.3.1 Requirements

Requirements provide the stakeholders' view of what they expect the software system to provide. They indicate what the software system must do, but do not explicitly express how it must be done. They identify the value of the system in respect to the opportunity and indicate how the opportunity will be pursued via the creation of the system.

As such, requirements serve like a medium between the opportunity and the software system. Among the biggest challenges software teams face are changing requirements. Usually, there is more than one stakeholder in an endeavor, and stakeholders will of course have different and even conflicting preferences and

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opinions. Even if there is only one stakeholder, he/she might have different opinions at different times. Moreover, the software system will evolve together with the requirements. What we see affects what we want. Thus, requirement changes are inevitable because the team's understanding of what's needed will evolve. What we want to prevent is unnecessary miscommunication and misunderstanding.

At TravelEssence, Smith encountered this when working on a discount program. The team had thought that this enhancement would be very simple. However, the stakeholders had different ideas on how long the program should last, which group of users the discount program should focus on, the impact of the discount program on reservation rates, etc. They had wanted to launch the discount program within a month's time, yet there was a great deal of debate even to the very last hour.

Thus, how a team works with requirements is absolutely crucial, with principles like:

- ensuring that requirements are continuously anchored to the opportunity;
- organizing the requirements in a way that facilitates understanding and resolves conflicting requirements;
- ensuring that the requirements are testable, i.e., that one can verify that the software system does indeed fulfill the requirements without ambiguity; and
- using the requirements to drive the development of the software system. In fact, code needs to be well structured and easy to relate back to the requirements. Progress is measured in terms of how many of the requirements have been completed.

4.3.2 Software System

The primary outcome of a software endeavor is of course the software system itself. This software system can come in one of many different forms. It could be the app running on your mobile phone; it could be embedded in your air conditioner; it could help you register for your undergraduate program; it could tally election votes. It could run on a single machine or be distributed on a server farm in data centers or across a vast network as in the Internet today.

Whatever the case, there are three important characteristics of software systems necessary before they can be of value to users and stakeholders: functionality, quality, and extensibility.

The need to have *functionality* is obvious. Software systems are designed and built to make the lives of humans easier. They each must serve some functions, which are derived from the software system's requirements.

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The need for *quality* is easy to understand. Nobody likes a software system that is of poor quality. You do not want your word processor to crash when you are finishing your report, especially if you have not saved your work. You want your social media posts to be instantaneous. Thus, quality attributes like reliability and performance are important. Other qualities, such as ease of use or a rich user experience, are becoming more important as software systems become more ubiquitous. Of course, the extent of quality needed depends on the context itself. This again can be derived from the software system's requirements.

The third characteristic is that of being *extensible*. It can be said that this is another aspect of quality, but we want to call this out separately. Software engineering is about changing and evolving the software system, from one version to the next, giving it more and more functionality to serve its users. This evolution occurs over time as a series of increments of more functionality, where every increment is described by more requirements. This is illustrated in Smith's job at TravelEssence, which involves introducing changes to the existing travel reservation software system when TravelEssence introduces new discount programs, initiates membership subscription incentives, integrates with new accommodation providers, etc.

There are several important aspects of this evolution. First, it does not merely entail hacking or patching code into the software system. Otherwise, as the software system grows in size, it will be harder to add new functionality. Consequently, teams often organize software systems into interconnecting parts known as components. Each component realizes part of the requirements and has a well-defined scope and interface. As a student, the lessons you will learn about object orientation, etc. are about organizing the software system into manageable components.

Second, code needs to be well structured and easy to relate back to the requirements. Just as the requirements will evolve, the software system needs to be extensible to such changes.

Third, the evolution involves transitioning the software system across different environments, from the developer's machines, to some test environment, to what is known as the production environment, where actual users will be using the software system. It is not unusual to find that software that works on the developer's machines will have defects (or bugs) in the test or production environment. Many senior developers get irritated when they hear novices say: "But it works on my machine." A developer's job is not done until they system works well in the production environment. A quality software system must:

- have a design that is a solution to the problem and agreed to;
- have demonstrated critical interfaces;

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- be usable, adding value to stakeholders; and
- have operational support in place.

4.4 Software Engineering Is Also about Endeavors

An endeavor is any action that we take with the purpose of achieving an objective, which in our case means both delivering value according to the given opportunity and satisfying stakeholders. Within software engineering, an endeavor involves a conscious and concerted effort of developing software from the beginning to the end. It is a purposeful activity conducted by a software team that achieves its goals by doing work according to a particular way of working.

4.4.1 Team

Software engineering involves the application of many diverse competencies and skills in a manner similar to a sports team. As such, a team typically involves several people and has a profound effect upon any development endeavor. Without the team there will be no software.

Good teamwork is essential for high performance. It creates a synergy, where the combined effect of the team is much greater than the sum of individual efforts. But getting to a high-performance state does not come naturally; instead, it results from a deliberate attempt to succeed.

To obtain this high level of performance, the team members should reflect on the way they work together and how they focus on the team goal.

Teams need to:

- be formed with enough people to start the work;
- be composed of personnel possessing the right competencies/skills;
- work together in a collaborative way; and
- continuously adapt to their changing environment.

When working in TravelEssence, Smith belonged to a development team. Although members of Smith's team had slightly different skill sets, they collaborated to achieve the team's goal together. Smith was particularly focused on backend technologies (i.e., the part of the software system running on the cloud), whereas Grace, a colleague, focused on front-end JavaScript and React Native technologies. (Since these technologies are not the emphasis of this book, you don't need to know them. Moreover, technologies change rather quickly. Instead, what we want to

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emphasize is that effective teams have to address the opportunity presented to them to satisfy stakeholders.)

4.4.2 Work

When a team comes together to do the work of making the opportunity a reality in the software system they build, the purpose of all their efforts is to achieve a particular goal. In general, there is a limited amount of time to reach this goal: they must get things done fast but with high quality. The team members must be able to prepare, coordinate, track, and complete (stop) their work. Success in this has a profound effect upon meeting commitments and delivering value to stakeholders. Thus, the team members must understand how to perform their work and recognize if the work is progressing in a satisfactory manner.

Doing the work, then, involves:

- getting prepared;
- communicating the work to be done;
- ensuring that progress and risk are under control; and
- providing closure to the work.

In TravelEssence, Smith and his team managed their work through a backlog. The backlog is a list of things to do, which originated from requirements. They communicated regularly with their stakeholders to make sure that their backlog was accurate, up-to-date, and represented the stakeholders' priorities. In this way, they could focus on getting the right things done.

4.4.3 Way of Working

A team can perform their work in different ways and this may lead to different results. It can be performed in an ad hoc manner, meaning that you decide how to work while doing the work. For instance, while cooking a soup, you may not follow a recipe—you might decide on the fly which ingredients to use and in what order to mix and cook them together. When following an ad hoc way of working, the result may or may not be of high quality. This depends on many factors: among them, the skill of the people involved and the number of people involved in the process.

All of us are acquainted with the saying "too many cooks spoil the broth." If too many cooks cook the soup in an ad hoc manner, the soup won't taste good. Translating the analogy to software, if too many people participate in agreeing on how to do the job, the job will probably not be done well. There are many reasons

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for this. One of them is that each person has his/her own idea of how to conduct the job and, often, they do not work in an orchestrated manner.

Smith's team addressed this issue by regularly looking at their prioritized backlog. They made sure that they correctly understood the scope of each item in the backlog, checking with stakeholders and getting feedback from them. Smith's team regularly examined their method or, in other words, their way of working. If things did not seem right, they made changes.

It is therefore important for team members to come into some kind of consensus regarding their way of working. Disagreements about the way of working are significant barriers to team performance. You would think that coming to an agreement would be easy. The truth of the matter is that it is not. On a small scale, within a single team, there is still a need for members to agree on the foundations and principles, followed by specific practices and tools. This would of course need to be adapted to the team's context, and evolve as the environment and needs change.

The way of working must:

- include a foundation of key practices and tools;
- be used by all the team members; and
- be improved by the team when needed.

In an industry scale, one of the things we hope to achieve through Essence is to simplify the process of reaching a common agreement. We do that at this scale by identifying a common ground or a kernel and having a way to deal with diversity of approaches. In the subsequent chapters, we will discuss the approach taken by Essence in greater detail.

In this chapter, we have introduced the following terms: opportunity, stakeholders, requirements, software system, work, team, and way of working. Essence will give these terms greater rigor and provide guidance to software teams on how to build a stronger foundation to achieve their goals.

What Should You Now Be Able to Accomplish?

After studying this chapter, you should be able to:

- list and explain the things involved in all development endeavors, related to the customer (i.e., opportunity, stakeholders), solution (i.e., requirements, software system), and endeavor (i.e., work, team, way of working);
- give examples of different types of stakeholders, together with their interests and concerns;

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- explain the mediating role of requirements;
- name and explain the three key characteristics of software systems (i.e., functionality, quality, and extensibility); and
- explain what makes a good team.

Understanding the facets of software engineering covered in this chapter provides an overview of the main core of Essence. This core may seem fairly abstract at this point, but as you read on, you will recognize all these facets in the Essence alphas, and be able to apply them in more and more practical and detailed ways.

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5

The Language of Software Engineering

The goal of this chapter is to present how the concepts discussed in the previous chapter are expressed as a language similar to how a programming language is expressed in computer science. Thus, we learn the concepts of alpha, alpha state, work product, activity, activity space, competency, and pattern, and how these concepts are expressed. We will show in this chapter

- the language constructs of Essence;
- the role of alpha states in two alphas and related checklists;
- the meaning and benefits of essentializing a practice; and
- the concept of cards as a practical way to use the various language elements of Essence.

What you learn here provides the necessary handles to use Essence in practice!

5.1 A Simple Practice Example

Essence provides a precise and actionable language to describe software engineering practices. Just as there are constructs like nouns and verbs in English, there are constructs in the Essence language in the form of shapes and icons. Just as a child learns a language by first using sentences without understanding the underlying grammar, we will introduce the Essence language through a simple pair programming practice. We choose this very simple practice because it is easily understandable even for students new to software engineering. We will introduce more sophisticated ones in later parts of the book.

We describe this programming practice as follows.

- The purpose of this practice is to produce higher quality code. In this case, we assume that the concept of code quality is understandable to the different members of the team.

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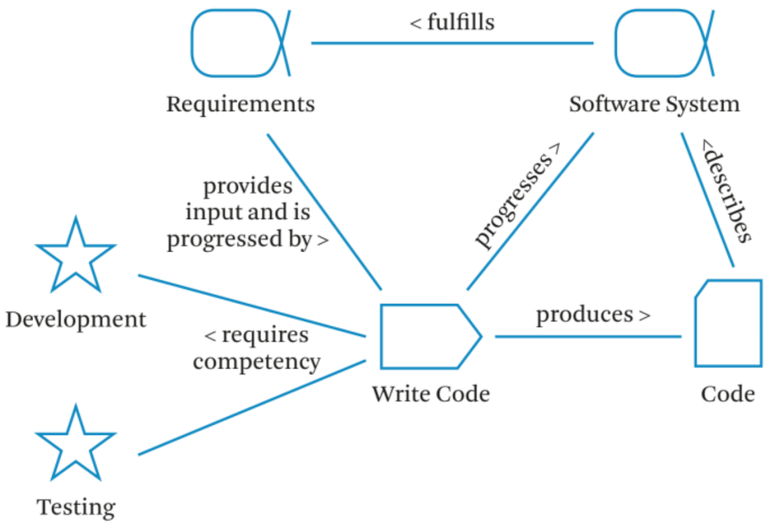

Figure 5.1 Simple programming practice (pair programming) described using Essence language.

- Two persons (students) work in pairs to turn requirements into a software system by writing code together.
- Writing code is part of implementing the system.

Essence uses shapes and icons to communicate the Things to Work With, the Things to Do, and Competencies. We shall describe each of these categories in turn and at the same time demonstrate how Essence provides explicit and actionable guidance for them, delivered through associated checklists and guidelines.

Figure 5.1 shows the elements in our simple programming practice. The shapes and icons are the constructs, i.e., the "nouns" and "verbs," in the Essence language.

These different shapes and icons each have different meanings, as quickly enumerated in Table 5.1. As the text continues, we will go into greater depth for each one of them and explain their significance.

5.2 The Things to Work With

The "things to work with" in our programming practice are requirements, software systems, and code. If you compare the icons in Figure 5.1 with their definitions in Table 5.1, you will see that two of these are alphas, but one is a work product.

Essence distinguishes between elements of health and progress, which are called alphas, versus elements of documentation, which are known as work products. Alphas are the important intangible things we work with when conduct-

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