Type of the Paper: Book Review
Received: 22.12.2021
Accepted: 31.12.2021
DOI: https://doi.org/10.18485/edtech.2021.1.1.6
UDC: 51-7:004(049.32)

“Essential Discrete Mathematics for Computer Science”, Harry Lewis, Rachel Zax, Princeton University Press, 2019 Book review

Ana Savić [1,*] and Nikola Popović [2]

[1] Academy of Technical and Art Applied Studies, School of Electrical and Computer Engineering, Belgrade, Serbia;, ana.savic@viser.edu.rs
[2] Alfa BK University, Faculty of Mathematics and Computer Science, Belgrade, Serbia; nikolap6901@gmail.com
* Correspondence: ana.savic@viser.edu.rs; Tel. 00381(0)63/665-828

Abstract: The book entitled Essential Discrete Mathematics for Computer Science by authors Harry Lewis and Rachel Zax, published by Princeton University Press in 2019, constitutes an important contribution to the study of the mathematical foundations of computer science. In addition to an introduction to discrete mathematics as a science, this 400-page book presents us with as many as thirty-one shorter chapters and a large number of exercises (more than 300). The importance of this book primarily stems from its good organisation, because each chapter of the book is suitable for one lecture, i.e. every chapter is a separate lesson with concluding analyses and problems suitable for homework or group exercises in class, so it is useful for both undergraduate and master studies in the field of mathematics in information technology. Because of its unique concept and simplicity of presentation, a large number of examples and proven formulas and theorems, the book is valuable to students and professionals who use discrete mathematics in the field of computer science.

Keywords: discrete mathematics, graph, logic, cryptography, finite automata

1. Introduction

Essential Discrete Mathematics for Computer Science covers mathematical concepts required for computer science. It is used as a textbook for the subject of the same name taught by one of the authors (namely Prof. Lewis) at Harvard University. In the Introduction section, the authors state the following: “We stress the art of proof in the hope that computer scientists will learn to think formally and precisely” and it is exactly the aforementioned word “proof” that is the highlight of this book and a part of this methodology.

In addition to a large number of exercises, all formulas and theorems are fully proven, which further strengthens the importance of this book and its application in the education of undergraduate or master students, because it fits into the curricula of different subjects and different study levels due to its unique concept. As the book has a wide range of research, it can be applied to numerous courses, depending on the conceptualised curricula.

2. Authors

Harry Lewis has been teaching as a professor of Computer Science at the Harvard School of Engineering and Applied Sciences since 1974 and served as Dean of Harvard College from 1995 to 2003. He is an American computer scientist and mathematician well known for his research in computational logic and textbooks on theoretical computer science. Rachel Zax, AB in mathematics and secondary in computer sciences (Harvard), is a Google software engineer.

3. The Structure of the Book

The concept of the book implies as many as 31 short chapters, wherein each lesson is accompanied by a summary and about ten problems related to the topic of the lesson in question. The chapters are organised into four parts: Logic; Automata and Formal Languages; Discrete Probability; and Modular Arithmetic and Cryptography.

Chapter 1, entitled “The Pigeonhole Principle”, discusses the general computer program behaviour principles and reasoning through function or mapping, sets, the pigeonhole principle, the extended pigeonhole principle, sequence, as well as the fundamental arithmetic theorem. Chapter 2, entitled “Basic Proof Techniques”, teaches how to take informal, specific arguments and how to have them translated into formal, general, mathematical proofs. Chapter 3, entitled “Proof by Mathematical Induction”, first of all, states that the first step in solving a problem is understanding what it says. Based on this syntagm, the authors explain mathematical induction in terms of the base case, the induction hypothesis and the induction step. Chapter 4, entitled “Strong Induction”, discusses the shortcomings of mathematical induction and a way to overcome these shortcomings.

Chapter 5, entitled “Sets”, speaks about a set as a collection of distinct objects, which are called the members of the set, whereas Chapter 6, entitled “Relations and Functions”, discusses a relation as a connection between various subjects, not only numbers, and a function as the type of a kind of binary relation. Chapter 7, entitled “Countable and Uncountable Sets”, explains countable and uncountable sets, whereas Chapter 8, entitled “Structural Induction”, explains proof by induction and its importance for computer science concerning establishing the truth of propositions. Chapter 9, entitled “Propositional Logic”, presents a lesson on propositional logic and the importance of precision in communication with computers, whereas Chapter 10, entitled “Normal Forms”, teaches normal forms, and explains and proves the difference between other forms regarding the relation to the defined norm. Chapter 11, entitled “Logic and Computers”, teaches the connection between and the importance of logic and computers, explaining bits, true and false "0" and "1", whereas Chapter 12, entitled "Quantificational Logic", explains the logic of expressions such as "for any", "for all" and so forth. Chapter 13, entitled "Directed Graphs", presents the reader with directed graphs as binary relations, whereas Chapter 14, entitled "Digraphs and Relations", presents digraphs and relations and Chapter 15, entitled "States and Invariants", is a lesson about the discrete state of digital computers.

Chapter 16, entitled "Undirected Graphs", explains an undirected graph as a collection of vertices connected. Chapter 17, entitled "Connectivity", deals with the connectivity of these graphs within a social or computer network. Chapter 18, entitled "Coloring", teaches us a lesson about graph colouring problems, and Chapter 19, entitled "Finite Automata", is dedicated to finite automaton and its importance for small parts of a computer system. Chapter 20, entitled "Regular Languages", further discusses the field of finite automata by dealing with regular languages as the languages that the field accepts, whereas Chapter 21, entitled "Order Notation", deals with computation problems. Chapter 22, entitled "Counting", explains counting, including finding a general formula for this function, whereas in Chapter 23, entitled "Counting Subsets", counting subsets are explained. A series as a sum of similar terms, perhaps a product of similar terms, is explained in Chapter 24, entitled "Series". Chapter 25, entitled "Recurrence Relations", is about recurrence relations. Chapter 26, entitled "Probability", explains the probability and possible outcomes of the system behaviour, and Chapter 27, entitled "Conditional Probability", explains conditional probability. Chapter 28, entitled "Bayes' Theorem", presents the theorem of British mathematician Thomas Bayes (Nyberg, 2018), whereas Chapter 29, entitled "Random Variables and Expectation", speaks about random variables and expectation. The last two chapters, namely Chapter 30, entitled "Modular Arithmetic", and Chapter 31, entitled "Public Key Cryptography", teach the reader about modular arithmetic and public-key cryptography, respectively.

4. The Strength of the Book

The book entitled Essential Discrete Mathematics for Computer Science addresses a broad range of readers, although it was primarily written as a textbook for Harvard University intended for teaching the course of the same name. The authors and the publisher recommend it as compulsory reading for undergraduate and master courses related to the subject of this book, including other mathematical modules (such as linear algebra and calculus). Therefore, the book is formulated as a 31-lesson textbook accompanied by exercises through proving the formulas and theorems, and inclusive of summaries and supplemental materials for instructors upon request as well. The book is also recommended for others who need a book with an emphasis on proof.

The book is characterised by a good concept and it is organised well. The methodology used by the authors is visible, logical and systematically leads the reader deeper into the field of the research this discipline does. The chapters are organised into four parts: Logic; Automata and Formal Languages; Discrete Probability; and Modular Arithmetic and Cryptography. The selected methodology facilitates the readers' understanding and learning, whereas insisting on proof, which is manifested in the form of the complete proof of the set theorems and formulas, is conducive to better learning outcomes. The systematic quality and consistency demonstrated in the book are indicative of the authors' great empiricism. Through metaphors and analogies, such as the famous "Hilbert's Hotel" (Kragh, 2014), the authors summarise the chapters, and the lessons are illustrated by a sufficient number of figures that infuse additional value to this book.

5. Conclusion

Essential Discrete Mathematics for Computer Science is a unique method of understanding the mathematical foundation of computer science because it is the basic discipline of many computer sciences. In their book, the authors define the subject matter of the research study, which includes the thirty-one lessons necessary for understanding and using postulate discrete mathematics in computer science. The book by Harry Lewis and Rachel Zax is written in a way that makes it possible to teach the reader mathematical reasoning and proving skills. It is primarily useful for instructors, because it offers a manual with available solutions. The book is also valuable to students, researchers and professionals in the field of computer science, as mathematics is the basis of many computer disciplines.

The authors use metaphors and analogies to explain to the reader the application of discrete mathematics in computer science and present a large number of illustrative examples that will make it easier for academic readers and computer professionals to understand the lessons. The book provides computer scientists with complete material for lectures and exercises in discrete mathematics in computer science course and in other courses that insist on mathematical laws and proofs.

References

1. Lewis H, Zax R (2019). Essential Discrete Mathematics for Computer Science. Princeton University Press.
2. Harry Lewis BlogSpot. [cited 5.12.2021]. Available from: http://harry-lewis.blogspot.com/.
3. Kragh, H. (2014). The true (?) story of Hilbert's infinite hotel. [cited 5.12.2021]. Available from: http://arxiv.org/abs/1403.0059.
4. Nyberg, S.O. (2018). Bayes' Theorem (chapter) The Bayesian Way. DOI: 10.1002/9781119246909.ch6.