Search Methods in Artificial Intelligence

Search Methods in Artificial Intelligence is designed to provide in-depth knowledge on how search plays a fundamental role in problem solving. The book is meant for undergraduate and graduate students pursuing courses in computer science and artificial intelligence. Starting with basic search, it covers a variety of complex algorithms designed for different kinds of problems. It demonstrates that search is all-pervasive in artificial intelligence and equips the reader with relevant skills.

The text begins with an introduction to search spaces that confront intelligent agents. It illustrates how basic algorithms like depth first search and breadth first search run into exponentially growing spaces. Discussions on heuristic search follow along with stochastic local search, algorithm A*, and problem decomposition. The role of search in playing board games, deduction in logic, automated planning, and machine learning is described next. The book concludes with a coverage of constraint satisfaction.

Deepak Khemani has been actively working in the field of artificial intelligence (AI) for over four decades – first as a student at Indian Institute of Technology (IIT) Bombay and then as a Professor in the Department of Computer Science and Engineering at IIT Madras. Currently he is Professor at Plaksha University, Mohali. He has three well-received courses on AI on SWAYAM, a MOOC platform launched by the Government of India. He is also the author of *A First Course in Artificial Intelligence* (2013).

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Deepak Khemani

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Shaftesbury Road, Cambridge CB2 8EA, United Kingdom
One Liberty Plaza, 20th Floor, New York, NY 10006, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India
103 Penang Road, #05–06/07, Visioncrest Commercial, Singapore 238467

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www.cambridge.org
Information on this title: www.cambridge.org/9781009284325

First published 2024

A catalogue record for this publication is available from the British Library

ISBN 978-1-009-28432-5 Hardback
ISBN 978-1-009-28433-2 Paperback

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Contents

Cambridge University Press & Assessment
978-1-009-28432-5 — Search Methods in Artificial Intelligence
Deepak Khemani
Frontmatter
More Information

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Preface

This book is meant for the serious practitioner-to-be of constructing intelligent machines. Machines that are aware of the world around them, that have goals to achieve, and the ability to imagine the future and make appropriate choices to achieve those goals. It is an introduction to a fundamental building block of artificial intelligence (AI). As the book shows, search is central to intelligence.

Clearly AI is not one monolithic algorithm but a collection of processes working in tandem, an idea espoused by Marvin Minsky in his book *The Society of Mind* (1986). Human problem solving has three critical components. The ability to make use of experiences stored in memory; the ability to reason and make inferences from what one knows; and the ability to search through the space of possibilities. This book focuses on the last of these. In the real world we sense the world using vision, sound, touch, and smell. An autonomous agent will need to be able to do so as well. Language, and the written word, is perhaps a distinguishing feature of the human species. It is the key to communication which means that human knowledge becomes pervasive and is shared with future generations. The development of mathematical sciences has sharpened our understanding of the world and allows us to compute probabilities over choices to take calculated risks. All these abilities and more are needed by an autonomous agent.

Can one massive neural network be the embodiment of AI? Certainly, the human brain as a seat of intelligence suggests that. Everything we humans do has its origin in activity in our brains, which we call the mind. Perched on the banks of a stream in the mountains we perceive the world around us and derive a sense of joy and well-being. In a fit of contented creativity, we may pen an essay or a poem using our faculty of language. We may call a friend on the phone and describe the scene around us, allowing the friend to visualize the serene surroundings. She may reflect upon her own experiences and recall a holiday she had on the beach. You might start humming your favourite song and then be suddenly jolted out of your reverie remembering that friends are coming over for dinner. You get up and head towards your home with cooking plans brewing in your head.

So, in principle at least one can imagine a massive neural network that could do all the above. But how would it be implemented? What kind of a training process would instil all such knowledge and memories in the neural brain? Human beings go through a lifetime of learning. A human baby, unlike a fawn, is an utterly helpless creature and needs to be nurtured for years. Taught in schools, influenced by peer groups, moulded through culture and religion, coached in sports. Every human is said to be unique, even identical twins. We celebrate this diversity, even when it is sometimes a source of crime and conflict. Are we ready for idiosyncratic machines? Or do we aim for identical assembly line robots? But what or who would they be like? And what about issues of fairness? And generation of harmful or misleading content?

The twenty-first century has seen an explosion in machine learning as exemplified by deep neural networks which outperform humans on many classification tasks, and large language models that can generate an essay, a college application, or a poem in a jiffy. Massive computing power and humungous amounts of data have made this possible. It has been very impressive, but has it peaked? Do we need to move on and seek another path to the Holy Grail, machines which autonomously solve problems for us? Instead of blanket ingestion of all data on the internet, perhaps we need to build machines which learn from human expertise to become experts in specific domains. And do useful things for us.

This book is a step in that direction. It is designed to be a complete guide to one specific aspect of problem solving – the use of search methods. It is intended to be one in-depth module for the task of building AI, and its contents can be covered in a one semester course. We begin by learning to walk with small problems, and gradually build a repertoire of search algorithms that would allow us to navigate the high seas and vast deserts. The algorithms are general purpose, but our representations are tailormade for the individual domains. We urge the interested reader to implement the algorithms described here and develop a suite of search algorithms that can be used to solve specific problems.

One common feature in all these algorithms is that they operate on symbolic data, where symbols stand for things meaningful to us, and algorithms operate upon them. This approach is, as *hypothesized* by Herbert Simon and Alan Newell in 1976, both necessary and sufficient to create AI.

Maybe one day these many algorithms and the different problems they solve will come together in an integrated entity as a step towards artificial general intelligence. But that will need advances in knowledge representation where different domains and problems can be uniformly expressed in a common language. There is work still ahead for us.

Acknowledgements

Several people have contributed in myriad ways to this book, some directly and some indirectly. Many students in my class, both online and offline, have triggered a thought process by asking incisive questions and making insightful observations. I gratefully acknowledge all of them collectively. They have made the job of teaching and learning rewarding.

Baskaran Sankaranarayanan has been involved with my courses over the last few years, answering student queries, helping with question papers and figures, and most importantly by standardizing the way in algorithms are written in pseudo code. He has written the appendix in this book on algorithm style, and the algorithms in the book conform to that style.

Sutanu Chakraborti has been a long-time collaborator working in AI. He wrote a chapter on natural language processing in my previous book, *A First Course in Artificial Intelligence.* In this book he has written one chapter on machine learning, despite a pressing schedule.

I am indebted to the following who have read and commented upon parts of the book – Nitin Dhiman, Aditi Khemani, Kamal Lodaya, Adwait Pramod Parsodkar, Devika Sethi, and Shashank Shekhar.

I am grateful to the team at CUP for their constant support from the very beginning. Vaishali Thapliyal took up my book proposal with gusto and got reviews from external reviewers expeditiously, yielding some very valuable suggestions and feedback. When the manuscript was ready Vikash Tiwari and Ankush Kumar initiated the production process immediately. Aniruddha De and Karan Gupta have done an excellent job with proofreading and copy editing, ironing out many discrepancies and bringing uniformity to the writing style.

Finally, I would like to thank the friends and family who have supported the book writing in many ways.