PREFACE

The grand challenge in artificial intelligence (AI)[a] is to build truly general intelligent systems,[b] systems that have the same intellectual capacity as humans, i.e. able to make meaningful decisions, learn and exhibit their intelligence in a general way in complex environments and across many different domains.

There have been many efforts made in the past decades to meet this challenge since Alan Turing, in 1950, first proposed the Turing test to validate machine intelligence. The quest has led to much progress in AI research. However, the advances made are largely in very specific or isolated domain and cannot be generalized well for wider applications. To refocus on the original vision of building a truly general intelligent system, more recently, attention has been turned towards the computational model of the human brain.

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[a] Artificial Intelligence (AI) refers to the branch of science that attempts to create intelligence in machine. The definition here includes computational intelligence such as fuzzy, artificial neural network, probabilistic inference and evolutionary computing and intelligent agents approach.

[b] General intelligent system is used here for the same purpose and meaning as general artificial intelligence or strong artificial intelligence. In the aspect of mimicking the brain, it is also known as cognitively intelligent system or brain-inspired computing system or human-like cognitive system or cognitive computing or computational cognitive system. Note that some scientists may be more specific than others in defining and classifying these terminologies.

Unlike current AIs, which are limited in many ways, the human brains possess the ability to autonomously process information in complex environments, automatically learn relevant information, and can associate the right information for handling surprises in diverse domains and situations. The brain's processing power in terms of size, power consumption, plasticity and the robustness is something we would like an intelligent system to have.

The human brain and its intelligence continues to be a fascinating subject. With the recent advances in measuring instruments such as two-photon laser scanning microscopy and fMRI, the neuronal connectivity and circuitry of how the brain's various regions are hierarchically interconnected and organized are better understood now than ever before. Computer scientists hope that by reverse engineering of the brain, we may able to build cognitively intelligent systems that have this truly general intelligence ability.

This book provides a walkthrough on the quest for building general intelligent systems based on an understanding of the brain. It brings together diverse viewpoints and expertise from multidisciplinary communities that are interested in understanding and modeling the brain and mind machinery.

The book starts by providing an overview of how the brain is structured. Chapter 1 guides the readers through the various brain regions and their functions. Chapter 2 provides a description of the neurons and the synapse connections. It addresses how neurons communicate and how information is stored. Chapter 3 looks at the cortex architecture and describes the hierarchical structure design of the cortex. Specific hierarchical pathways in the cortex are discussed. Chapter 4 presents the different types of memory systems that researchers understand from studying the brain. Chapter 5 looks at the learning capability of our brain: How learning takes place and what are the various learning schemes. Chapter 6 addresses the issue of how emotion gives rise to cognition.

Each of these chapters (Chapters 1 to 6), the computational challenges to design and model the cortex from the regions and networks of neurons to the individual neuron's models is also

discussed. The various designs of the hierarchy fashion from different stages i.e. from column or mass of cells to a few cells, and the computational design concept from simple to complex cells are presented.

From Chapter 7 through Chapter 10, the different design concepts of the whole brain from the computational to the cognitive science perceptive, are summarized. Chapter 7 and Chapter 8 summarize two unique perspectives of computing approaches to designing of the brain, namely laminar computing and probabilistic computing, respectively. Chapter 9 discusses on the higher theories of the brain and commonsense knowledge representation and generation. Chapter 10 provides the model of the entire brain based on cognitive architecture.

What are the prospects of building a truly general intelligent system? How soon can we create a machine with human-like intelligence? Chapter 11 explores these issues and the challenges. Many scientists give differing opinions. Some scientists believe that human-like intelligent systems will emerge within two decades.

Why is understanding and modeling of the brain difficult? Chapter 12 addresses the issues involved and discusses why access to today's modern instruments is still limited. With these limitations, it would be no surprise that only now and then would we hear or read about news of a new brain theory or a new discovery that gives new insight to the brain and mind. Chapter 13 presents the principles we can adopt to build intelligent systems from our current understanding of the brain. Chapter 14 concludes with a brief discussion on the theory of the mind.

The human brain remains a source of the great wonder and mystery. It exists in us and yet we do not feel its presence. We perceive with our mind day in and day out. I hope this book will provide some fresh perspective and thought in our quest to build truly general intelligent systems from an understanding of the brain.