Preface

This book describes how a theoretical neuroscience can be established that creates understanding of how higher cognition is generated by neurochemical, physiological and anatomical processes. The route to this theoretical neuroscience lies through the application of the techniques for understanding extremely complex electronic systems. Despite the ubiquity of such systems, these techniques are not generally appreciated. The most complex systems contain many billions of components like transistors, each performing its functions in a way that results in the features of the system. Design of transistors, design of integrated circuits, design of printed circuit assemblies, design of frames and system design must all be integrated together and the hardware design must be integrated with the design of software and the design of compilers to translate software into a form that can act on the hardware. Many people have written software or content for computer systems such as those supporting the internet, without necessarily understanding the immense problems that have been solved to make such activities possible.

From 1969 to 1999 I was employed by a company that was one of the first to design extremely complex electronic real-time control systems. When I joined the company, it was called Northern Electric, when I left it was called Nortel Networks, and for a number of years the research and development activities in which I worked were moved to a separate subsidiary called Bell Northern Research (BNR).

Over my career, the company (which I will call Nortel) was the pioneer in shifting telecommunications networks from an older technology based upon electromechanical switches to the new technologies of silicon and software. Being the pioneer meant that Nortel needed to become proficient in all the required technologies. These technologies included design and manufacture of transistors, integrated circuits, printed circuit assemblies and systems with thousands of such assemblies. The company developed the design tools, manufacturing capabilities and testing capabilities for all these technologies. In addition, Nortel developed the languages, compilers and the design environments and tools for the required software. System architecture was heavily affected by the requirement that one system could not be totally out of service for more than 2 hours in 40 years, for example resulting in the requirement that software upgrades be made "on the fly" on actively operating systems. The first systems were introduced in the 1970s, and by the early 1980s one system had around four billion transistors packaged into integrated circuits. The initial design of such a system took about 5,000 engineering man years, and after introduction a system required constant evolution to add and modify features.

At different times in my career, I had responsibilities in most of the different hardware and software design areas. As a result, I obtained a good perspective on the many issues encountered in designing, constructing, testing, and modifying extremely complex systems. In the early 1980s I began to wonder about whether the techniques used to understand such extremely complex systems could be applied to the brain. This was not to suggest that there was any direct resemblance between electronic systems and brains, but rather that the approaches needed to understand the qualitatively different types of systems might have some common elements. My book on how such techniques could be applied to the brain was published in 1990 [1].

In 1999 I left Nortel to be able to devote myself full time to developing these ideas. After performing a number of simulations and writing a number of papers, a second book was published in 2005 [2] that made the system ideas more rigorous. In 2007 I created and began to teach a course at the Australian National University on this system architecture approach to the brain, integrating much more anatomical, physiological and neurochemical information into the architectural framework. The current book is the result of thinking about how this integration can occur.

I am indebted to the many people who worked at Nortel, and provided the remarkable intellectual environment which made complex system design possible. This intellectual environment was the stimulus leading to the system ideas about the brain. I am also indebted to the Computer Science department at the Australian National University for the opportunity to develop and teach the course on brain architecture, and especially to my long term collaborator Professor Tom Gedeon.

The book follows the presentation order of the ANU course. The intent is to provide enough psychology and neuroscience to allow computer scientists to understand the application of the architecture to the brain, and enough systems explanation to allow psychologists and neuroscientists to appreciate what the approach can contribute to integrating knowledge in those different fields.

Research School of Computer Science L. Andrew Coward
Australian National University
Canberra, Australia
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