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Review of *Neuroinformatics: An Overview of the Human Brain Project*

David A. Peterson

In 1990, President George Bush proclaimed the 1990s as the Decade of the Brain. The numerous disciplines trying to solve the puzzle of the brain and behavior fall under the umbrella known as the *neurosciences*. It is the fastest developing industry in the natural sciences (Koslow and Huerta 1997). Myriad methods and tools that come out of the computer and information sciences, collectively referred to as informatics, are being deployed to assist with the neuroscience research enterprise. Thus, at the intersection of neuroscience and informatics is *neuroinformatics*. *Neuroinformatics: An Overview of the Human Brain Project* is an enlightening snapshot of this evolving field.

The primary federal vehicle for propelling the field of neuroinformatics is the Human Brain Project. It was initiated in response to a report published by the National Academy of Science's Institute of Medicine's 1989 Committee on a National Neural Circuitry Database (Martin and Pechura 1991) and is funded by 16 organizations across 5 federal agencies: (1) National Institutes of Health (NIH), (2) National Science Foundation, (3) United States Department of Defense, (4) National Aeronautics and Space Administration, and (5) United States Department of Energy. Additional background and perspective can be found in Huerta and Koslow (1996). The Human Brain Project is being led by the National Institute of Mental Health (NIMH), one of the NIH institutes.

The book's editors, Stephen Koslow and Michael Huerta, are the director and associate director, respectively, of the Division of Basic and Clinical Neuroscience Research at NIMH. *Neuroinformatics: An Overview of the Human Brain Project* is a progress report from the first phase of federal funding for the Human Brain Project. Reports from some of these first projects make up the majority of the book, with the balance of the book providing an overview of neuroinformatics. The book's foreword provides interesting history and perspective on the incubation of neuroinformatics. The preface and first two chapters of the book explain neuroinformatics and the motivation for it. As with so many other fields, there has been an information explosion in neuroscience research. Data are produced by tens of thousands of investigators in hundreds of journals. The typical annual meeting of the Society for Neuroscience, for example, has over 10,000 individual presentations. Furthermore, neuroscience data are complex and varied. These data span many orders of magnitude in both time and space dimensions, with phenomena from microseconds to years and from nanometers to tens of meters; come in many forms, including text, images, and time series; come from the analysis of a wide range of species, from simple invertebrates to humans; and come from many levels of analysis, ranging from the molecular to systems to behavior. All these dimensions are explored in both normal and diseased organisms.

Neuroinformatics: An Overview of the Human Brain Project, *editors Stephen Koslow and Michael Huerta, Lawrence Erlbaum Associates, Hillsdale, New Jersey, 1997, 376 pages, ISBN 0-8058-2099-X.*

The book goes on to point out that neuroscience has also witnessed extensive specialization, with specialties as diverse as molecular geneticists and cognitive psychologists. As a result, it is becoming increasingly difficult to integrate data outside one's specialty, making it less likely that conceptual links will be formed between disciplines. Fortunately, the past few decades have seen a parallel improvement in the accessibility of advanced computing resources, including both hardware and informatics software. How can informatics help the burgeoning field of neuroscience? The book outlines several ways:

First, one needs to recognize that neuroinformatics is not simply another scientific computing application in disguise. Whereas most scientific computing applications are specialized, neuroinformatics is meant to be an integrative approach. Researchers can create models that integrate information and provide a simple way to test, online, hypotheses about the system under study. This test, in turn, provides a benchmark for comparison of experimental results. Thus, neuroinformatics supports the loop between models and experiments. Geographically distributed investigators can contribute to evolving models through networked software applications. In contrast, modeling and empirical work, historically conducted by different parties, previously involved information exchange that was indirect and through printed media. Neuroinformatics can help investigators make better use of complex data. The data can be stored in robust databases and accessed through intelligent navigation, visualization, and manipulation tools. Furthermore, neuroinformatics tools can facilitate virtual experiments, in which data originally collected to test one hypothesis can later be used again to test other, new hypotheses without having to sacrifice additional animals. However, the neuroinformatics challenge is not simply a matter of applying bread-and-butter informatics technology to neuroscience research. The systems need to be interoperable, both between projects within the Human Brain Project and between Human Brain Project initiatives and other related initiatives, such as the Human Genome Project. Also, the community will have to address tough issues commonplace in the evolution of modern science, such as intellectual property rights and the distribution of prepublication data.

After the first two chapters, the book includes progress reports from eight projects representative of the host of projects funded by the Human Brain Project. The SenseLab Project investigates models of the olfactory system as an example of sensory system information-processing models. The GENESIS (general neural simulation system) Project focuses on powerful general-purpose simulations, from the biophysics of subcellular components to the collective behavior of networks of cells. The GENESIS simulator has seen widespread use for several years now and is a recognized leader in the computational neuroscience community. Chapter 5 outlines a project that sets out to integrate information on neural circuitry across various species, systems within the brain, and levels of analysis. The remaining five projects described in the book involve neuroanatomy of one form or another. One describes a streamlined environment for collecting, analyzing, and viewing magnetic resonance images, with an emphasis on microscopic magnetic resonance imaging (MRI) and central nervous system development. Because many of the computationally expensive operations are done on a per voxel basis, the investigators have designed the system to spread computations across a network of workstations. Yet another project uses morphometrics in the study of gross neuroanatomy. Another has developed a digital atlas of the human brain, combined with a general framework to support both structural (for example, computerized tomography, MRI) and functional imaging modalities (for example, functional MRI, positron emission tomography, electroencephalography, magnetoencephalography). One specific project, the Digital Anatomist Program at the University of Washington, has focused on the structural organization of brain areas used prominently in language. The last project described in the book focuses on the general-purpose theme of quantitative image analysis. Unfortunately, the project descriptions reflect an emphasis on structure over function, an increasingly antiquated approach in neuroscience. In my view, neuroscience (and neuroinformatics in particular) would be well served to shift emphasis toward functional imaging technologies. Despite the close relationship between structure and function throughout the brain, complete understanding of how the brain works will never be achieved without understanding its gross physiology. From the perspective of neuroinformatics, functional imaging could take advantage of recent advances in multidimensional time-series–analysis methods.

Taken together, the projects leverage a wide spectrum of tools well known to computer scientists. Most projects use some form of client-server architecture, with a general-purpose relational database as the back end and a web-based interface providing both geographic and platform independence. Many projects involve at least some custom software development, with languages common to AI systems, including C, C++, SMALLTALK, and Lisp. The graphics and visualization aspects of some projects are impressive, applying surface and volume model extraction from magnetic resonance images (Chapter 6), the use of brain-map morphing techniques to ascertain subtle anatomical differences between normal and psychiatric subjects (Chapter 7); and the use of robust, high-end commercial data-visualization products such as Advanced Visual Systems' AVS (Chapter 9).

This book is relevant for virtually all neuroscientists and informatics researchers, including a large portion of the applications-oriented computer science community. The informatics aspect of the book can easily be gleaned from the text by readers with no neuroscience background at all. However, to understand the neuroscience aspects of the book, the reader needs a basic background in neuroscience. If you are looking for a book that demonstrates the application of informatics to neuroscience, this book is a good read. It makes a compelling argument that informatics can help put a cohesive slant on the immense, diverse, and largely disparate field of neuroscience. If you are looking for a book that demonstrates the application of AI techniques to neuroscience, you will not find it here. Beyond some simple intelligent agents and Bayesian classifier–based machine-learning algorithms, the projects outlined in this book contain little in the way of AI techniques. This is not a criticism of the book; AI techniques have not yet played a significant role in most informatics domains. I believe that there are a multitude of AI techniques that could supplement neuroinformatics, including neural networks, genetic algorithms, fuzzy reasoning, and data mining. This book clearly demonstrates that neuroscience is embracing many of the basic tools available from computer science. However, if one of the goals of the Human Brain Project is to encourage investigators to adopt cutting-edge computing technology, then the neuroscience community needs to open its arms to AI as well. Perhaps future reports from the Human Brain Project will include exciting news about how AI has helped neuroscientists unravel the mysteries of the brain.

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David A. Peterson was formerly a network and business reengineering consultant with Andersen Consulting. His is currently a Ph.D. student at Colorado State University in the Department of Computer Science. His e-mail address is petersod@cs.colostate.edu.