Book Reviews

Neurons, Perception, and Communication

Philip Swann

Images and Understanding: Thoughts about Images, Ideas about Understanding, H. Barlow, C. Blakemore, and M. Weston-Smith, eds., A collection of essays based on a Rank Prize Fund's International Symposium, organized with the help of Jonathan Miller and held at the Royal Society in October 1986, Cambridge University Press, Cambridge, United Kingdom, 1990, 401 pp., ISBN 0-521-34177-9 (cloth), ISBN 0-521-36944-4 (paper).

This volume is a well-written, informative, and thought-provoking collection of essays that should interest anyone concerned with the psychology of vision and visual communication. The aim of the original symposium was to bring together people from the arts and sciences who could present different perspectives on the subject of images and understanding. The result is an informal tour conducted by leading specialists (predominantly British) that visits both famous scientific battlefields and quaint artistic backwaters. Numerous striking pictures enliven the book: Here you can find the sensory somatic cortex of a bat, the British miners' leader Arthur Scargill in full rant, a notation for ballet, a mole used to advertise British Gas, instructions for righting a caravan, and many others.

The 23 essays originated in diverse disciplines, among them biology, psychology, art history, and linguistics. They are grouped according to the sessions in which they were presented under thematic titles: The Essence of Images, Movement, Narration, Making Images, Images and Thought, and Images and Meaning. However, the desire to have a good interdisciplinary mix in each session renders the already generic session titles meaningless; for example, John Krebs's contribution on animal language is included in the Narration session following David Lodge's discussion of viewpoint in the novel! Further, the essays themselves stay firmly within the territory of the authors' expertise: They are either overviews of the state of the art or a piece of work in progress at the time of invitation. I found that the only way to make sense of the volume was to deconstruct it and reassemble the essays according to their original disciplines, hence my title and the order that I follow in this review. The stated interdisciplinary claims of the editors are further weakened by the absence of discussion among the participants themselves; they do not even say if such discussion took place. Therefore, it is left to the reader to judge if the whole is greater than its parts, which is what I try do in this review.

Neurons

Starting with the pioneering (and Nobel Prize–winning) work of David Hubel and Tosten Wiesel, neurobiologists have made remarkable progress in uncovering the structure and function of the visual system in higher animals. The results of this work have important implications for our understanding of the brain as a whole. Writing in this collection, Colin Blakemore quotes the steering committee of the 1986 Systems Development Foundation Symposium on Computational Neuroscience. The question under consideration is as follows: Is physical locality an essential part of neural computation? According to position 1, "Brain function is determined by the logical and dynamic connection properties of its neurons. The actual physical structure, location, architecture, and geometry is irrelevant to its logical, connectionist aspects." In contrast, for position 2, the anatomical structure of the brain "may represent a major mode of brain function: the formatting of sensory data in a manner which simplifies its further processing" (p. 262). The neurobiological contributions in this collection all strongly support position 2: As more and more special-purpose machinery is identified in the brain, less and less space is left for general-purpose computation.

In "What Does the Brain See? How Does It Understand?" Horace Barlow presents the anatomy of the brain, visual pathways, cortical maps, and the structure of receptive fields for individual neurons. This system transforms the raw image projected onto the retina into a cortical image that has been filtered and restructured in many ways. However, as it is held in the primary visual cortex, this image is still largely a meaningless bitwise representation. How does the brain find objects and relations in the image (rather, in sequences of images), or as Barlow puts it, how does the brain understand what it sees? It is a measure of progress made that this question no longer seems silly, and Barlow's answer seems plausible. He suggests that the cells in the primary visual cortex "grow into other cortical areas where they create new patterns in which the information is brought together according to new principles that are not necessarily related to the topography of the original image" (p. 21). Thus, the primary area carries out local feature detection by way of selective sensitivity to texture, motion, and so on, but these secondary areas synthesize new higher-level images according to Gestalt-type principles.

Blakemore ("Understanding Images in the Brain") tackles the difficult question of functional interpretation in a way that complements Barlow's presentation. He points out that just because cells in the visual cortex are laid out as isomorphic maps of the sensory cells in the retina, it does not follow that the brain actually uses the information provided by the map (as opposed to the information carried by the individual cells and their connections). Indeed, the maps might be a simple artifact: "an inevitable but useless consequence of the fact that nerve fibres, growing from the sense organs to their targets in the brain, tend to preserve the same spatial pattern as that of the receptors in the sense organ" (p. 267). In other words, rearranging the cortical cells in a random pattern, while maintaining their connections, would have no effect on the information carried: Such a property would be characteristic of a connectionist model of the brain.

Blakemore is not a connectionist, and he offers several lines of argument to show that the information in the spatial patterns of neurons in the cortex is actually used by the brain. His first argument is that there are cortical maps that are not isomorphic. Edge-detecting cells in the visual cortex are one example. Together with the functional connections between maps, this is strong evidence that the brain is interpreting the maps themselves as well as their constituents.

Blakemore's second line of argument appeals to biological design constraints. First, he suggests that maps arise naturally from the low-level structure of the brain: "Most of the connections in the brain are short, local fibres, such that cells are either excited or inhibited by their close neighbours" (p. 276). Second, Blakemore claims that topographic maps facilitate the process of putting maps together into higher-level structures. Third, he argues that the genetic specification for building the brain must be small, so the procedural rules are likely to be simple; for example, "Make all nerve cells inhibit their immediate neighbors on either side" (p. 278). Theoretical models have shown that such simple rules for local interaction will replicate the properties of real nerve cells, provided that the input to the network is topographically arranged. The conclusion is that the infrastructure of the brain might well be similar or even identical throughout the cortex: Local functional specialization would be achieved by the nature of the input and their topographic distribution. In one of the most interesting points made in the whole book, Blakemore notes that the enormous increase in the size of the mammalian brain appears to be owed primarily to the addition of more and more sensory areas; he remarks ironically that higher intelligence might thus be a consequence of an increase in perceptual resources rather than symbolic computational power.

The remaining neurobiological essays describe work on the function of neural subsystems that provides supporting evidence for the general principles proposed by Barlow and Blakemore. David Perret and his coauthors in "Three Stages in the Classification of Body Movements by Visual Neurons" offer a superb demonstration of what the monkey brain can achieve at the higher levels of visual processing. They have recorded the response of individual neurons in the temporal cortex to various kinds of visual stimuli. It turns out that neurons in this area are selective for specific kinds of objects, movements, and events; in other words, visual knowledge is hard wired. By studying the responses of hundreds of such cells, the authors established some of the main subpopulations. They found that there are cells selective for the six canonical translations in three dimensions (3-D) and point out that at least in English, we have names for them and only them (up, down, left, right, toward, and away). Similarly, there are cells selective for one of the six orthogonal views of the head: "Thus information about body view and direction of motion appears to be segregated into channels of processing which use the same three-axes system" (p. 96).

Further investigation is revealing even higher levels of specialization. The authors have strong evidence that although most neurons are selective according to the viewer's frame of reference, others actually respond with respect to an actor- or object-centered frame of reference! They exhibit one such cell that responds to arm movements that bring the hand in front of the face independent of the orientation of the actor with respect to the viewer. Finally, other cells are sensitive to goal-directed actions, for example, an actor walking toward the door of the laboratory. Moreover, the visual understanding encoded by such cells does not directly cause motor or emotional reactions: An actor leaving the laboratory results in different behavioral responses, depending on the circumstances, for the same visual neuron response. As the authors point out, cognitive scientists do not usually admit such goal-centered descriptions as a part of vision: "Understanding of actions is seen as requiring logical inference based on previous experience. This attitude ignores the fact that the database and processing from which a comprehension of actions can be made, can be purely visual and does not necessitate the use of language" (p. 107).

Although the neurological work has obtained the most spectacular results, evolutionary biologists are also working on the visual system. In "Tricks of Colour," John Mollon begins with the instructive history of the theory of color vision. It was the polymath Thomas Young who pointed out in 1801 that trichromacy is a property of our visual system, not the physical world; he even guessed correctly that there are just three classes of receptor cell in the retina tuned to select for specific subranges (blue, green, and red) of the visible spectrum. Recent work has shown that the biology of the color visual system is even more surprising than its structure: Asymmetries in the trichromatic system suggest that "our colour vision depends on two rather different subsystems, one recently overlaid on the other" (p. 67). The ancient system is dichromatic (blue, green) and is found in most mammals and some other lower animals; it is insensitive to spatial detail and provides almost purely chromatic information. The more recent trichromatic system, found in humans and other Old World primates, is apparently the result of a duplication of the gene that coded the long-wavelength pigment (green) in the ancient system. Further, the new dimension of color is parasitic on an edge-detecting system of cells and, consequently, is sensitive to spatial detail. Other recent research has elucidated the genetic mechanisms that give rise to the various types of color blindness, and Mollon concludes with some astonishing results concerning the mothers of color-blind men. It is apparently possible that some of these carriers are actually tetrachromatic and, thus, enjoy an extra dimension of color discrimination!

Perception

What is the relation between our everyday subjective experience of the visual world and the rapidly developing scientific knowledge concerning the neurobiological medium of this experience? In other words, are we any closer to seeing how the brain can be a mind—and vice versa? The neurobiologists contributing to this collection do some hand waving in the direction of these questions, but the substance of their contribution regards the science of brain function. The rapid emergence of this new science has, I think, rather caught psychologists and philosophers who deal with such issues off guard, an impression that is confirmed by their contributions to this collection.

With Richard Gregory's piece "How Do We Interpret Images?" the discussion moves to the psychological level of neuropsychology: "The key problem for perception is how meaning is read from neural signals from the senses" (p. 310). The senses of touch, taste, or smell can directly signal biologically significant stimuli such as heat, cold, and food. In contrast, images are only representations of stimuli: They have to be interpreted before meaningful action can follow, and it is this interpretation that delivers perception from sensation, thus the initial meaning of the image. With respect to this process of interpretation, Gregory characterizes the two main schools of thought in the theory of perception as passivist and activist, James Gibson and Hermann Helmholtz being, respectively, perhaps the best-known exponents of each school. The distinction is slippery to say the least but is fairly clear in its most extreme form: The passivists hold that perception is an almost direct grasping of sense data, but a radical activist treats visual perception as functionally similar to language understanding. Thus, the activist will favor a top-down style of analysis in which knowledge and expectation drive perception, with visual illusions offering decisive supporting evidence. The line of research started by David Marr might at first sight be considered passivist, but Gregory suggests that workers in this area really belong to a third school, the algovists, occupying a middle position. *Algovists* differ from traditional activists in that they emphasize abstract formal properties of the image, such as the laws of perspective, rather than specific knowledge of objects.

At first, the distinction between the algovist and activist approaches might seem vague and unworkable, but in the second half of his essay Gregory shows how it can be made operational in the experimental study of visual illusions. Take, for example, Rubin's classic faces-vase figure. A person who had seen faces but had never seen a vase would presumably not see the figure as ambiguous. This case is a clear-cut example of acquired knowledge about specific object types determining perception. Illusory surfaces and contours, such as those seen in the Kanizsa triangle, are rather different, and Gregory's discussion is not easy to follow. He apparently suggests that these ghostly surfaces are a kind of limited case of the general subjective phenomenon of object completion; for example, a car parked behind a lamp post is not perceived as a car with a vertical slice missing! Evidence that the illusory surfaces are algovistic rather than knowledge based is not hard to find. First, the surfaces apparently require contours that are the completion of simple, smooth curves. Second, Gregory and others have shown that the illusion is generated early in the visual system, in some cases before stereo fusion, and, thus, prior to higher-level cognitive processing. Finally, "a disturbing feature of all illusions is that we can be perceptually illuded [sic] while at the same time knowing this—so we are not conceptually deluded" (p. 329).

Gregory concludes with some speculations regarding the relative independence of perception and conception. First, if what we perceived was dependent on what we know, then it would be impossible to see anything new. Second, it would be vastly redundant and biologically costly (or impossible) to check everything we see against everything we know. Finally, Gregory says, "When we study illusory contours and ghostly surfaces, we see what we know is illusion. Could this separation between perception and conception be the distinction between 'subjective' and 'objective', and so divide art and science, so that we live with two kinds of meanings?" (p. 330).

Three other contributions deal with higher-level aspects of perception. In a disappointing piece, "Pictures in the Mind?" Nelson Goodman issues the familiar philosophical warnings about mental imagery, recalling the long-running debate in the cognitive science community over Stephen Kosslyn's work. It is apparently dangerous to speak loosely of mental images or pictures because "having an image amounts not to possessing some immaterial picture in something called a mind but to having and exercizing [sic] certain skills—a matter of producing, judging, revizing [sic] certain material pictures and descriptions" (p. 362). In a postscript entitled "On Understanding Mental Images," Roger Shepard, who made mental imagery respectable again with his famous experiments on mental rotations, replies to Goodman. He agrees that we have to be careful about the vocabulary, but don't really get into trouble if we remember that "mental imagery is of external objects, and is therefore to be defined and studied not as some strange, non-material 'picture in the head' but in relation to potential test stimuli that are both external and physical" (p. 370). Finally, in a fascinating historical survey, "Scientific Images: Perception and Deception," Jon Darius shows how scientists are frequently led to see what they want to see in visual images, prejudiced by their theories and beliefs. Here, however, "seeing" refers to the entire process of interpretation with respect to sociocultural context; thus, it lies largely beyond the ken of current psychology and neurology.

Computer-Generated Images

Work on the manipulation of images by computers is of two main types: In computer graphics, the goal is to produce an image from a mathematical model, but in computer vision, the goal is to extract a mathematical model from a given image. For example, given the equation for a curve, we can program a computer to draw the curve on screen or paper, but given a bit image of a curve, we can try to solve the much harder problem of finding the equation that best fits it. An easily drawn analogy between computer vision and human vision has led to a certain exchange of ideas between the two fields. Some cognitive scientists have taken the analogy seriously and claimed that at some level of abstraction, the brain is solving the same problem using the same methods as the computer; so, a theory of human vision can be tested by implementing it as a program.

Three essays in the collection discuss computer-generated images. Andrew Witkin et al., "Linking Perception and Graphics: Modeling with Dynamic Constraints," present a nontechnical view of some recent work in building mathematical models of objects in the physical world. Lansdown's "Understanding the Digital Image" is an equally nontechnical description of the ray-tracing techniques used to give computational representations of 3-D scenes. Neither of these contributions suggests connections between their work and human perception.

In "Computer-Generated Cartoons," Andrew Pearson, E. Hanna, and K. Martinez do argue for such connections. They developed software that will extract a digital line drawing (a cartoon) from a photograph. The goal is to produce a system that can create moving cartoons from video and transmit them across data networks; this technique would allow, for example, the deaf to communicate by sign language through a telephone line. The authors found quickly that simple two-dimensional edge detection was unsatisfactory and hypothesized instead that cartoon lines should correspond to the 3-D points where lines from the camera or eye were tangent to the surface of the human face in the image. An analysis of the way light falls on faces showed that the loci of these tangent points lay in luminous valleys or at step edges, allowing the authors to design a detector that could extract the loci as lines from a digitized photograph. The result is remarkably effective and compares favorably with cartoons produced by a human artist from the same photographs.

The cartoons generated by the system of Pearson and his colleagues have a remarkable property: If they are passed through the system a second time, they do not change. The authors also note that their detector is functionally similar to known low-level neural filters in the retina and visual cortex. In addition, there are clear connections with "Marr's idea of a 'raw primal sketch' as a first processing step in the representation of shape information in the human visual system" (p. 55). These and other considerations led the authors to claim that the computer and cartoonist essentially replicate the work of the first stage of human visual processing. Thus, the cartoon will set up the same response in the early visual system as the photograph from which it was extracted!

Visual Communication

Most of the remaining contributions to the symposium come from the arts and humanities. Viewed as science, they can loosely be classified as dealing with semiotics. If the neuropsychologists work bottom up, the semioticians are resolutely top down. They start with human communication in its full complexity and, armed almost solely with conceptual analysis, attempt to elucidate general principles and mechanisms at work in all forms of communication. Whatever its cultural value, semiotics has so far yielded little of scientific interest. This failure might be because the arbitrary and conventional character of cultural systems excludes them from the domain of science, or it might be because real progress in semiotics can only follow from progress in neuropsychology. This statement is the working assumption of some neuropsychologists, explicitly stated by Barlow: "This book is being published in the belief that an account of what goes on inside the skull is relevant for those who are mainly concerned with the external world, and that the latter group have [sic] knowledge of the ways that images are linked, connected, and meaningfully manipulated that can aid scientific understanding of the mysteries of the mind" (p. 25).

Despite this pious hope, the conceptual apparatus of the two groups is completely disjoint, and there are no clear connections between them. That said, the contributors provide an interesting anthology of the data and styles of analysis used in semiotics and the humanities. Ernst Gombrich gives a history of pictorial instructions, from sixteenth-century fencing manuals to airline safety leaflets. Monica Parker and Kenneth MacMillan present "Benesh: The Notation of Dance," a shorthand that can record the complexities of classical ballet. In "What Does Gesture Add to the Spoken Word?" Peter Bull gives a fascinating analysis of the use of gesture in political speech making. With a careful study of a video, Bull shows how Arthur Scargill's verbal rhetoric is accompanied by gestures that control the audience's applause; thus, he "creates the impression of overwhelming popularity, continually struggling to make his message audible both by speaking into the applause and by using gestures to restrain it" (p. 119). In "Are the Signs of Language Arbitrary?" Margaret Deuchar concludes, rather confusingly, that they are in fact conventional, which is surely what linguists mean by arbitrary. Lodge's piece, "Narration," gives the literary critic's understanding of viewpoint in story telling, and John Willats's "The Draughtsman's Contract: How an Artist Creates an Image," provides analogous comments regarding representational conventions in drawing.

More hope for genuine interdisciplinary progress surely lies initially in the study of visual signals used for communication by animals. Such signals mark the boundary between the tightly constrained world of neurological visual processing and the unconstrained world of conventional symbolic systems created by human societies. By attacking from both sides, we clarify the boundary itself and the phenomena it separates. Michael Land's contribution, "Vision in Other Animals," deals not with communication but rather with the optics of vision in three remarkable invertebrates: the scallop, the boatman, and the jumping spider. The spider is famous for its acute eight-eyed vision, incorporating, for the principal pair of eyes, a movable retina behind the fixed lens. "Like our own eyes, each has six eye muscles, and these move the retina up and down, side to side, and also cause it to rotate around the visual axis" (p. 208). This remarkable system is used to detect prey, predators, and potential mates. However, Land does suggest that the complex movements of the retina correlate with edge-detecting neurons to facilitate the identification of "conspecifics" by checking for their characteristic leggy silhouette: "If we assume that the retinae contain rows of receptors that link up to 'line detectors', then the scanning pattern is understandable; the rotational movements would provide the detectors with a range of orientations, and the lateral movements can be thought of as hunting for matches between the detectors and the contours" (p. 210).

The title of Krebs's essay, "Animal Language," leaves no doubt that he is discussing communication, but "animal signals" would have better reflected the account he gives. Animal signals, he points out, usually convey simple messages about immediate events: Keep out, I am a male, and the like. However, many such signals have evolved into complex ritualistic displays, tempting one to assume that the original simple message has also become semantically complex. Krebs argues that this assumption, in fact, is not the case, as follows: Before animals used signals at all, they interacted in various ways that affected their reproductive probabilities. Natural selection would favor individuals who could anticipate important actions of their neighbors. For example, it is to the advantage of dog B to anticipate a bite from dog A by evasively responding to A's tooth baring. However, now A can force B to take evasive action simply by baring its teeth! It is at this point that tooth baring has become a genuine signal; indeed, Krebs defines signals as "behaviour patterns used by actors to manipulate the behaviour of reactors to the advantage of the actor" (p. 158). The story doesn't end there because it is now to B's advantage to treat the signal as a bluff, which leads A "to increase the persuasive power of the signal by, for example, exaggeration, elaboration, repetition and any other device that might overcome sales-resistance" (p. 159).

A beautiful example of how elaborate such persuasion can become is provided by the Australian satin bowerbird. The males of this species build complex and decorated bowers to attract the females. Mating success is directly related to bower showiness: In one study, the most successful male mated 30 times, the least successful not at all. Why would females succumb to this rather nouveau riche approach? It turns out that the males steal each other's decorations and sometimes destroy the bower of a rival; so, bower showiness can be read as a measure of the male's ability to defend and steal and, thus, is a good metric for potential mates.

In conclusion, Krebs notes that from evolutionary continuity, it follows that animal signals must contain, in embryonic form, some of the characteristics of human communication. However, it is too easy—and nearly always wrong—to read such characteristics back into animal signals.

Conclusions

It will be clear, I think, that the intellectual style of this symposium was far removed from the heated ideological clashes so characteristic of cognitive science and AI in the United States. Indeed, one might be tempted to dismiss the book as not being about the real issues, such as they are to be found, for example, in the pages of the journal *The Behavioral and Brain Sciences*. All the buzzwords are missing: There is no mention here of information processing, symbolic computation, neural networks, the modularity of mind, knowledge representation, and so on. Although not including such terms could be explained as a concession to the audience and the occasion, I think, in fact, that it genuinely reflects the contributors' views on the state of the art. Further, this low-key, pragmatic approach has a lot to recommend it. The style comes from biology rather than cognitive science, and the emphasis is on the phenomena themselves rather than on data, models, and theories.

The book reflects the remarkable progress made by neuropsychology. Working from the bottom up, neurologists have shown that sensory processing in the brain is localized and highly structured into partly autonomous subsystems of diverse evolutionary origin. Working in the middle, psychologists are beginning to establish how this processing structure constrains our visual experience. However, understanding an image is something that happens right at the top when the conscious, reflective self interprets a symbol with respect to a language, a culture, and its own remembered experience. Nothing is said in this book about the vast, largely uncharted area of the brain where this interpretation happens, where the results of perception are synthesized into conscious experience, translated into action, and integrated with memory. Further, nothing is said—and presumably little is known—about the way that top-level processes feed knowledge back to the visual system to support recognition and learning. Even when the neurologists complete their description of the brain's functional architecture, any proposed theory of understanding will still have to tackle the social and conventional grounding of human semiotic systems.

In strictly scientific terms, then, the symposium was premature—perhaps by several decades! However, the approach it took gives some interesting pointers to the future of cognitive science. First, the account of the visual system (and by implication of the brain as a whole) is far removed from any unified computational theory of mind and brain. Our head apparently contains a loose assemblage of hundreds of systems put together by evolution at various times and places. As biologists reconstruct the origin, purpose, and history of these systems, it is becoming increasingly difficult to distinguish the psychological from the biological. Second, several of the essays show the importance of working at the boundaries of domains. For example, the boundary between simple behavioral interactions and actual communication in lower animals is now a tractable problem for neurobiology; we can hope to learn the evolutionary mechanisms that took some species across this boundary. Third, the symposium confirms a shift in emphasis away from higher-level cognitive processes, such as language and logic, toward lower-level sensory processes such as object recognition. Finally, the book leaves me with the feeling that we might be seeing the beginning of a natural history of the mind in which the evolutionary assemblage of the brain as a ragbag of ad hoc solutions is rather similar in spirit to the social and cultural assemblage of its higher-level contents!

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Natural Computation

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Natural Computation, Whitman Richards, MIT Press, Cambridge, Massachusetts, 1988, 561 pages, $25.00, ISBN 0-262-68055-6.

Natural Computation by Whitman Richards is a collection of research papers on perception and motor control. It is divided into four main parts plus an introduction. "Image Interpretation: Information at Contours," the first major part, includes work on edge detection and classification, motion, representation and interpretation of smooth curves, and the inference of three-dimensional shape. "Image Interpretation: Property Tags: Color, 3D Texture, Flow Fields," part 2, includes articles on illumination, edge classification, image velocity, texture, computer graphics, and fractal descriptions. Part 3, "Sound Interpretation," includes work on the representation of acoustic information, speech recognition, separation and location of sounds using two ears, the recognition and interpretation of sounds and music, and the physiology of singing. The final part, "Force Sensing and Control," includes articles on grasping, sensing, hand design, manipulation, motion, and the geometry and dynamics of walking.

In part 1, Richards explains his approach to perception research, advocating the careful analysis of the information-processing tasks of biological systems, leading to reasonably clean, fairly abstract descriptions of the solutions. Richards acknowledges his debt to Marr; indeed, Richards's approach appears to have nothing new, although the presentation is too obscure to know for sure. Most of the articles in the book are, in fact, studies of diverse issues using (or inspired by) Marr's methods and vocabulary. They are, for the most part, written by Richards and his students and colleagues. Although many of the articles address interesting topics, and some propose interesting ideas, most are disappointing. I focus on a few articles that reveal specific recurrent flaws.

Michael Riley addresses the problem of detecting peaks in spectral cross-sections using the analogy of phonologists interpreting spectrograms of speech. By applying various filters and experimenting with their parameters, he achieves good performance. Unfortunately, spectral interpretation is not a particularly good source for insights into speech recognition, and the exact location of a peak is not a particularly useful feature to extract for speech understanding. The problem here of addressing a microproblem that is irrelevant to the larger task is the book's first recurring problem.

Three articles coauthored by Richards develop the idea of qualitatively representing the curvature of blob boundaries with strings of codons based on the sign of the derivative. These articles go into great detail on how to robustly extract codons in the presence of certain types of noise and some combinatoric analysis of possible silhouettes and three-dimensional shapes. This work is not well related to the larger context of vision; indeed, it is not at all clear whether an image can reliably be split into blobs. The research discussed here is not compared with other work, the second recurring problem with this book; there is also no information given to help the reader see how this article relates to the following one by Michael Brady and Alan Yuille on inferring three-dimensional orientation from two-dimensional contour. A third recurring problem is also evidenced here: failure to discuss what types of processing, if any, these representations, the codons, are useful for.

Staffan Truvé and Richards present an object description language motivated in part by a superficial analogy to grammars for natural language. This article investigates the mathematical properties of this and various auxiliary representations. This proposal is not related to work in solid modeling, nor is there any discussion of what tasks this representation is good for.

It is ironic that the failings of so many of the articles in *Natural Computation*—failure to keep the larger task in view, failure to compare alternative approaches, and failure to focus on processing—are ones that Marr was careful to avoid. However, many of the articles do closely follow Marr in other respects. Sometimes this approach works well, as in Steven Drucker's demonstration that it is not possible to recover texture information by touch unless the finger can stroke the surface, but often it results in limp mimicry, such as the proposal of a primal sketch for acoustic information.

Many of the authors seem equipped with little more than a strong mathematical background and a rigid version of Marr's methodology. The uninteresting, unconvincing, and irrelevant results illustrate that there is no real recipe for this type of research and that there is no substitute for broad and deep knowledge of the topic of inquiry. Another irony is that the strongest articles in the book are not particularly inspired by Marr at all. This group includes R. Von der Heydt et al. on the existence of cortical neurons that respond to illusory contours, Kent Stevens on the interpretation of three-dimensional shape from parallel surface contours, Edwin Land and John McCann on recovering absolute color and reflectance despite variations in illumination, Alex Pentland on fractal-based description of surfaces, Marc Raibert on balance and symmetry in running, and Johan Sundberg on the physiology of singing. Most of the merit of this book lies in the inclusion of these classic articles.

The reasons for including this particular set of articles are not given, however. One striking peculiarity is the lack of any exemplar of connectionist research despite an otherwise broad spectrum of methodologies (psychological, AI, Gibsonian, general systems theory). Given the existence of systems with impressive performance on tasks such as joint motion, speech recognition, and speech production, connectionism seems clearly relevant to natural computation, but Richards does not even comment on why connectionism doesn't qualify. Perhaps this omission is the result of an overly strict reading of Marr's injunction against premature low-level research.

An editor presenting such an eclectic collection has a special obligation to give the reader the necessary background, which, at a minimum, requires an introduction to every article. However, Richards only introduces the four parts of the book, and these introductions are poorly written and unfocused. There is a glossary, which helps, but it does not cover half of the technical terms introduced. The lack of historical background and adequate pointers to more recent developments in the field makes it difficult to understand the significance of some articles.

Physically, the book is a fairly durable paperback with a nice uniform layout. Unfortunately, so many errors were introduced in the conversion process (typographical errors, wrong references to numbers of parts and figures, poorly reproduced figures, and even missing text and references) that it might have been better to just photocopy the original articles. The author and subject indexes are thorough, and there are 110 problems in natural computation at the back to test your understanding of the articles and your ability to extend the results.

Richards fails to say why he produced this book or for whom; indeed, it seems to lack any audience. It will be rough going for readers without an extensive mathematical background and a broad knowledge of the fields covered. The book presents Richards's natural computation approach, but this seems to be merely a warmed-over version of Marr's approach, which is presented much more readably and convincingly in Marr's *Vision* (W. H. Freeman, 1982). *Natural Computation* is too scattered to serve as a reasonable survey of anything. Still, it might be of use to readers wanting easy access to seven or eight good papers in diverse fields who are also willing to ignore or sift through the chaff.

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