work is more briefly written up elsewhere in technical journals, but these are for an informed readership. The book was an opportunity to provide a distillation of profound ideas for a broadly based audience of scientific peers. The authors chose to write a tome.

SEARCH FOR COGNITIVE SCIENCE

Conceptual Structures: Information Processing in Mind and Machine.
By John F. Sowa.
Addison-Wesley: 1984. Pp. 481.

John Fox, Imperial Cancer Research Fund

Artificial intelligence has produced the latest new technology to enter popular awareness. "Expert systems" are advanced computer systems which solve problems that were previously thought to be the preserve of human beings; not just any human being, but experts. Artificial intelligence (AI) techniques are used to emulate (to a first approximation) the problem-solving and decision-making of the expert human mind. Systems for medical diagnosis, geological data interpretation, semi-conductor chip design, fertilizer selection, tax advice and so on have all been successfully developed to some degree, and the potential range of this new technology is enormous — even the emulation of exotica such as the military, scientific or political mind no longer seems entirely absurd.

In the middle of all this enthusiasm for "knowledge engineering" it is easy to forget that artificial intelligence is not new, and that it did not originally set out to be an engineering discipline but a science. The early workers defined their goal to be an understanding of the principles that underly intelligent behaviour in man, animals and (their special contribution) machines.

Artificial intelligence emerged in its modern shape when computers became available during the mid-1960s to scientists of many disciplines. Intelligence was seen as the capacity to manipulate symbols and, consequently, it could be understood in terms of symbol-manipulating models run on computers. Since the very early work on problem-solving and theorem-proving, researchers in AI have gone on to model the processes of visual perception, the understanding of language and speech, learning and the acquisition of intellectual skills, and even the formation of beliefs, social attitudes and the development of psychiatric conditions.

These subjects somewhat resemble those which have traditionally been the province of psychology. So what were psychologists doing during this period? Partly due to its own successes, and partly due to the influence of AI concepts, "cognitive psychology" was also developing rapidly in such fields as perception, memory, decision-making and so on. The relationship between the two communities was usually fraternal. The reference sections of psychological papers often acknowledged the contributions of AI, and vice versa.

Often, however, the acknowledgements were superficial only, and discussions were peppered with critical exchanges. Programmers in AI may be vigorous and inventive, say many cognitive psychologists, but they are not *scientists* with the normal discipline for careful, systematic enquiry that the term implies. The counter is that psychologists are obsessed with methodology. They miss the point, and the insights, of AI demonstrations of what is possible with symbol-processing mechanisms.

Over the past ten years there have been a few, but generally less than successful attempts at synthesis, although a name has been invented, "cognitive science", which is supposed to cover both scientific AI and cognitive psychology. Unfortunately most cognitive scientists are only well informed about one of the branches. They are also trained very differently and their books and journals show it. It is against this background that John Sowa's book appeared.

At first sight the book looks as though it might be something special indeed. The chapter headings cover a range of core ideas, including the philosophical basis of AI, reasoning and computation, language, psychological evidence and — above all — knowledge. Furthermore the preface declares that the book "combines AI and cognitive science approaches... In combining insights from each of the separate fields, the book gives a unified view of knowledge representation".

Sowa applies a general plan to each chapter wherever possible, the first few pages being background material containing wide-ranging discussion. These sections usually summarize psychological research and findings (in perception, language and so on) before going into more detailed, technical presentations on the same subject where the emphasis is on computation and formalization. Sowa maintains an attractive, readable style throughout the book, studded with illuminating illustrations of his points from a remarkable variety of fields ranging from optical illusions perceived by the peasants of Uzbekistan to the structure of early Greek poetry.

This has the feeling of a mature work, a long time in the making and reflecting years of serious thought. It is surprising therefore that the book includes chapters on recent topics such as knowledge engineering as well as classical ones. This is one of its strengths as Sowa is able to cut through some of the AI jargon and relate the new ideas to established topics such as data-bases and query languages. The references show the same careful mix; they are comprehensive but up to date throughout.

The most obvious manifestation of the book's maturity, apart from style and balance, is that Sowa manages to convince the reader that most of his diverse material can be brought together under a single theoretical idea, the "conceptual graph". This is a formal, symbolic structure which can be manipulated by a computer, and which can represent many types of human knowledge. By the end of the book one is convinced that the concept may be sufficient to support machine-reasoning, language (syntax and semantics), decision-making, learning and (just possibly) creativity. Those familiar with AI will find many familiar themes, but the integration of subjects and the extensive investigation of the formal properties of symbolic structures is impressive.

I am less sure about Sowa's discussions of the human equivalents of these machine processes. Certainly his knowledge of and respect for the work of psychologists is refreshing. There is even a hint of affection for people, which I often miss in the machine-obsessed books of the AI world, however good they may be technically. But while the psychological material broadens and enriches the book, to say that the fields are "unified" is a little strong. More significant, however, is that the attempt at "unification" is really an attempt attempt on the terms of AI, not those of cognitive psychology. The links which are made between the performance of programs and observations made by psychologists can be somewhat superficial and unconvincing. They appear to be included to show us that programs can show interesting features of intelligence, not that they have truly human characteristics of intelligence. There is little effort to consider whether the key concept of the conceptual graph can explain in any detail the things that the human mind does not do, as well as things it can do. One suspects that — like other AI ideas — the conceptual graph is powerful enough to encompass many bad theories of mind as well as good ones.

Conceptual Structures is not the missing classic, the book that really achieves a unification of the two fields, but it is one of the best attempts that I have seen. Perhaps the AI traditions of imagination and vigorous inventiveness are still too far from the scientific tradition of systematic experimentation respected by cognitive psychologists. The book is nevertheless instructive and entertaining, detailed but economical. It would be on my list of six AI books to take to a desert island, and any student of cognitive science will find it very rewarding.