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BOOK REVIEWS

Military enterprise and technological change edited by Merritt Roe Smith. The MIT Press, 28, Carleton Street, Cambridge, Massachusetts 02142, 1985, pp. 391, $ 34.50. Indian orders to Affiliated East-West Press, Madras 600 010.

The study of technological change and its interaction with the processes of society and its institutions is a rapidly growing scholarly discipline now firmly established in universities in Europe and America. The interaction has not always been a happy one and sometimes traumatic when the dynamics of a particular society has not been matched to the pace or shape of technological change. Technological growth has usually been unthinkingly identified with progress and the compulsions of powerful factions have often forced choices that could be detrimental to the larger long term social interest.

An agency that has determined the pace and direction of technological change is the military with its enormous powers of patronage. This book, *Military enterprise and technological change*, is a collection of commissioned essays edited by Merritt Roe Smith, Professor of the History of Technology at the Massachusetts Institute of Technology. They explore the role of the armed forces in American industrialisation, and the essays no doubt reflect in broad canvas if not in detail the corresponding influence in other societies. The influence has by any account been very large and many now commonplace and welcome features of civilian life have had their origins in military requirements. The need for reliability and maintenance of gun carriages and ordnance where components made in different parts of the country could be reassembled in the field with ease led to the development of a strict work discipline, the enforcement of standards in the quality of materials and processes, and the principle of uniformity that has become the foundation of modern interchangeable manufacture and mass production. The loss has been the disappearance of the autonomy and individual creativity of the craftsman which finally leads to one-dimensional man. To quote Mumford, an early pioneer in the study of technology and society, "it was unfortunate... that a power organisation like the army rather than the more humane and cooperative craft guilds presided over the birth of the modern forms of the machine".

The development of radio and the pattern of its use, the organisation of railway systems, the direction of post-war research programmes in psychology, much of modern management techniques, etc., have all been heavily influenced by military experience. These and very much more are discussed at length in this book. They make fascinating reading. Most of the essays are optimistic in their view of the military contribution. Not so David Noble in his essay on the social and economic consequences of military enterprise, who is willing to look closely at the accepted shibboleths and came up with some disturbing questions. In spite of market forces being central to the concept of a

capitalist economy, the very lynchpin of the system, the military seems to operate on monopolistic lines with far reaching economic and social consequences. It is argued that the cost maximising practice of military enterprise produces generations of managers "incapable of truly independent, innovative, efficient, or economical production – incompetent to produce for a competitive market". Noble persuasively argues that the widespread use of NC machines, pioneered for the needs of the US Airforce, has prevented the development of alternate methods of production that could be cheaper, more adaptive, and efficient. The heavy subsidies supporting the use of NC machines has for the first time since the 19th century made America a net importer of machine tools. American sociologists worry about the deskilling and downgrading of the work force by NC technology. These worries apply *a fortiori* to India and we should ponder the consequences of such technology inhibiting the accumulation of the skills necessary for a developing society to break out of technological dependence. To echo the questions raised in this essay, what kind of progress can we as a society afford? and progress for whom and for what?

This excellent book will be very useful to those interested in the interaction between technology and society. The rapidly growing industrialization of India and its social ramifications should be faced by our sociologists, historians and engineers who should examine and layout the possible choices and directions for us that need not be identical with those chosen by other industrial societies. This book and the growing number of titles on technology and society coming out of the MIT Press should be required reading for all interested in the technological future of this country.

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Guidance and control 1986 (Volume 61 of Advances in the Astronautical Sciences) edited by Robert D. Culp and John C. Durrett. American Astronautical Society, 1986, pp. 460, $ 60. Orders to Univelt, Inc., P.O. Box 28130, San Diego, CA 92128.

The volume is a record of the proceedings of the 1986 Annual Rocky Mountain Guidance and Control Conference in U.S.A. The conference series, which initially began as a local exchange of ideas, has been organised into a prestigious annual event which the aerospace community and, in particular, the workers in the guidance and control field all over the world look forward to.

The conference, and its proceedings, demonstrate a clear emphasis on topics related, directly or indirectly, to the guidance and control aspects of the US Strategic Defence Initiative (SDI). This is not surprising, given their national commitment to the programme, the extremely high level of technology involved in the guidance, control and pointing of the SDI components in space, and the level of scientific participation in the conference. The preface to the volume refers to a long tutorial on "Optics in control systems" with special emphasis on image defects. Although tutorial aspects are normally

not covered in conference proceedings, in view of the topical nature of the subject, perhaps a bibliographic summary would have enhanced the usefulness of the proceedings.

The first section of the book contains papers pertaining to control of large dynamic structures. This area is of direct relevance to the space station and large, flexible SDI spacecraft concepts. This section contains one analytical paper on computing nonlinear attitude manoeuvre controls and five other papers on systems aspects of the control of large dynamic structures. In an interesting paper, David Gilbert points out how the method of system-level verification so effectively employed for the success of the space shuttle avionic systems may not be practical or even possible in the case of the proposed space station because of mission differences and advances in technology in the intervening period. Another interesting contribution considers a low-authority passive-active control approach for attaining robust, reliable and less expensive control systems for the demanding task of fine-pointing and retargeting future large space structures. Also concerning a different aspect of fine pointing is the isolation of broad-spectrum vibration due to reaction wheels.

The second section of the volume, reflecting the session of guidance and control storyboard displays, has a series of interesting articles, most of them unfortunately in abstract form. The topics are diverse, including rendezvous and docking tracker, magnetically suspended isolation system, and high-speed chips for satellite arm control. In abstract form is an article of relevance to academics — Navigation, guidance and control curriculum at the Department of Astronautics of the US Air Force Academy. One would have liked to have some more details on this topic.

The third section dwells on the highly current and technology-intensive aspect of spacecraft attitude control challenges. The articles here deal with problems of extremely fine attitude control arising in modern spacecraft applications, in the presence of external and internal disturbances. A very interesting idea raised in an article in this section is the concept of accurate line of sight trajectory control of multiple payloads on an agile dual spin spacecraft using "synergistic control", *i.e.* allowing the spacecraft bus to undergo its natural motion in response to the moving payloads, while at the same time keeping track of this motion and using this knowledge to coordinate gimbal pointing and control torque commands to the various payloads. An inverse model of the spacecraft dynamics is used to obtain the gross component of motion through feed forward and fine compensation is obtained through feedback.

More articles on actual recent experiences with fine attitude control are presented in the final section of the volume. These include the space shuttle mission for the recovery of the Westar and the Indonesian Palapa satellites. This section also recounts other interesting experiences such as spacecraft gerontology and euthanasia with reference to the P78-1 satellite.

The penultimate section of the volume concerns orbital manoeuvre, transfer and servicing. A frontier technology area covered here is the experimental flight of the laser docking system. Descriptive articles on guidance and control of transfer orbit stage and

on the use of the orbital manoeuvring vechicle for placement and retrieval of spacecraft and platforms are included in this section.

Guidance and control 86 is undoubtedly a collection of high standard articles on the state-of-the-art in spacecraft guidance and control. The strength of the volume derives from the breadth and depth of coverage in this high-technology area and also from its authorship–scientists with direct involvement and experience in space programmes. In fact, perhaps the only major shortcoming of the volume is its confinement only to the US experience in this area. Certain earlier volumes in this series have devoted a section to the experience of other western nations and Japan. Even such a limited global view is found missing in this volume. However, because of the pre-eminent position of the US in frontier areas of space technologies, the volume still represents much of the world's best in this area.

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Legged robots that balance by Marc H. Raibert. The MIT Press, 28, Carleton Street, Cambridge, Massachusetts, 02142, USA, 1985, pp. 233, $ 34.50. Indian orders to Affiliated East-West Press, 6, Roselyn Gardens Apartments, 20/1A, Barnaby Road, Madras 600 010.

This is a fascinating book for any reader who is interested in understanding locomotion and using the underlying concepts for engineering applications. In spite of tremendous advances of automotive technology, one can observe that all 'natural' movements do not use the concept of a wheel that rolls without slipping and makes the centre move on a smooth surface. In nature, however, all animals move about using legs-bipeds, quadripeds, hexapeds and centipeds. It is, therefore, necessary to investigate as well as contemplate about this concept of 'legged robots'. Raibert's book is one such account. It is based on the research that his team has been conducting for the past ten years. His results and conclusions are not only interesting but are also thought provoking for other researchers working in the area of robotics.

Chapter 1 gives a brief history of legged machines. It also explains as to what is the motivation for studying animal motion as well as legged machines. Chapters 2 and 3 present a detailed account of Raibert's studies on a one-leg machine. Results of analysis, computer simulation and laboratory experiments of physical machines that run and balance on just one leg are described in these chapters. Contrary to expectations, it reveals that control of such machines is not particularly difficult. Studies of biped and quadraped running are described in Chapter 4. Besides forces and energy, one finds that locomotion has certain symmetry of pattern. This is particularly true in quadraped and hexaped machines. The aspects of symmetry have been wonderfully brought out in Chapter 5. Locomotion control is of paramount importance. Control aspects of

locomotion and running are discussed in Chapters 6 and 7. Chapter 8 describes the research activities being pursued in the area of animal locomotion and legged robots.

For a topic like locomotion, it is always difficult to convey the ideas through still photographs and printed words. The author has, thoughtfully, prepared a videotape, an appendix, to this book. The videotape certainly is helpful to visualize many concepts of locomotion.

The book has been published as a volume in the MIT Press Series on Artificial Intelligence. The editors of the series have always selected topics which are in the frontiers of technology. Legged robots is certainly one such topic that has immense potentials. In short, the book is a wonderful item for inquisitive reading as well as for research reference.

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Robotics research: The second international symposium edited by Mideo Manafusa and Mirochika Inoue. The MIT Press, 28, Carleton Street, Cambridge, Massachusetts, 02142, USA, 1985, pp. 530, $ 51.75. Indian orders to Affiliated East-West Press Pvt. Ltd., 6, Roselyn Gardens Apartments, 20/1A, Barnaby Road, Madras 600 010.

Robotics research is a rapidly advancing field in which almost all areas of engineering find their utility. The challenges of building intelligent machines have drawn an increasingly large number of researchers from different fields of science and technology into this novel and attractive field. As a result, a number of books, monographs and collections of technical papers exploring the current trends in robotics research have come into the market in recent years.

The volume under review is one such. It contains papers presented at the Second International Symposium on Robotics Research, held at Kyoto-Kaikan, Kyoto, Japan, 20–23 August, 1984, and published in the MIT Press series on Artificial Intelligence. All the papers presented in the symposium were invited ones. In addition to twelve technical sessions, there were two panel discussions in which papers were presented and discussed extensively. The volume contains all these papers including the comments of the panelists.

The professed aim of this symposium was to bring the world's leading researchers in this field together and providing extensive opportunities to discuss the current and future problems and issues of robotics. More than 50% of the papers presented were from the participants from the host country which is indicative of the rapid strides that Japan has made in the area of robotics. The volume will be of use to people who did not have the benefit of attending the symposium.

The papers can be grouped into four parts: Visual perception, Action control, Robot mechanisms and Task level studies.

The group of papers on visual perception contains studies on representation, recognition and location of 3-D objects, recovering of 3-D structures of surfaces from visual images, verification and determination of object configurations and identifications and location of overlapping objects using sparse local measurements. There is a subsection of papers on computer vision applied to alignment problem, object recognition systems, shape recognition methods, colour image processing and robot control.

The group of papers on action control basically deals with application of control theory to robotics and the kinematics and design aspects of robotics. This group includes papers on adaptive control algorithms, iterative learning schemes, collision avoidance problems, sensory information control, redundancy utilization using the concept of task priority, characterization, identification and estimation of contours and robot trajectories, tracking control algorithms, specification and generation of robot control algorithms, simulation systems for robot motion, solution of synthesis problem, estimation of errors in robot mechanisms, computer integrated advanced assembly systems and link mechanisms for force generation.

The third group of papers is on robot mechanisms like manipulators, end effectors and mobile robots. These papers deal with task control and description of dexterious manual operations by means of programs written in LISP, robots for precision applications and applications in farming industry like sheep shearing, micro-positioning methods using electro-magnetic impulsive forces, analysis of gripper-manipulators, design and construction of mobile robots with several legs, comparisons of legged and wheeled machines, morphology of legs, description of a guide dog robot and robot system for monitoring changes in environment.

The fourth and last group of papers elaborates on task level studies like modelling, programming, monitoring and theory of effective robot manipulation. They include works on solid modelling, robot map-making and navigation system, robot programming, execution monitor using rule-based system, scene modelling for robotic vision, collision-free trajectory planning and methodologies and software for analysing robot performance, manipulability measure of robotic mechanisms in positioning and orienting end effectors, and the design of novel performance indices for manipulators from the kinematic and static viewpoints.

The first panel discussion is based upon four papers exploring the various general and certain specific aspects of the future industrial research, development and application of robotics. A summary of the discussions is recorded.

The second panel discussion encompasses a larger area in the form of key issue of robotics research and is based upon five papers on robot vision, offline programming for robot sensors, measurement and control of flexible arms, reduction in complexity of programming robots, advanced robotics project in Japan and research trends in decisional and multisensory aspects of third generation robots. A brief outline of the discussions of the panelists is presented and provides valuable insights into the different viewpoints and the current and future trend in robotics research.

This volume covers a large area of interest in robotics research and contains valuable information on almost all of them regarding the major thrust areas in robotics. It is to be hoped that the book will be useful to people in the industry as well as research workers in the area.

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Computation and cognition: Toward a foundation for cognitive science by Zenon W. Pylyshyn. The MIT Press, 28, Carleton Street, Cambridge, Massachusetts, 02142, USA, 1984, pp. 292, $ 11.44. Indian orders to Affiliated East-West Press Pvt. Ltd., 6, Roselyn Gardens Apartments, 20/1A, Barnaby Road, Madras 600 010.

This book presents a systematic investigation of an approach to the study of functioning of brain that has come to be called cognitive science. The book is meant primarily for psychologists. It contrasts, through a thorough-going discussion, a computational view of cognitive science with other schools of thought like the behaviourism typified by stimulus-response theories and other related aspects like direct realism in perception. As the author himself puts it, the book is about explicating the foundational assumptions of cognitive science and carrying them to their logical end. Thus the book is meant more as an exploration rather than for setting down a theory of cognitive science.

The objects of study for cognitive science are species (and possibly machines!) that are endowed with mental capabilities which are generally referred to by the term cognition. The author takes the point of view that the main characteristic that distinguishes this group of 'cognizers' as a group is that they act on the basis of internal representations, *i.e.*, their beliefs and goals. The main question that arises is how is it possible for a physical system to act on the basis of 'knowledge of' objects and relations to which the system is not causally connected in the same way that forces and energy are related to behaviour in the physical realm. The main thesis of the book is that 'What makes it possible for humans to act on the basis of representations is that they instantiate such representations physically as cognitive codes and the behaviour is a causal consequence of operations carried out on these codes'. This amounts to the view point that cognition is a type of computation. The author suggests we need to look at cognitive phenomena from three distinct levels: the nature of the mechanisms that operate on the internal representations, called the functional architecture; the nature of symbol structures; and semantic content of cognitive codes.

For a computer scientist, the central thesis of the book is not totally new. That mental phenomena can be viewed as symbolic information processing tasks, is a view widely shared by researchers in artificial intelligence and is explicitly stated, for example, in the physical symbol system hypothesis of Newell and Simon. The main interest of the book, from the point of view of a computer scientist, is that it uncovers many of the implicit

philosophical and other assumptions underlying this approach to understanding the brain and also presents a detailed discussion on the kind of logical objections possible to this view. It answers most of them convincingly.

The author starts by arguing, in the first two chapters, that in order to explain cognitive behaviour, capturing all relevant generalizations, it is necessary to postulate internal representations and operations on the semantic content of these representations. Chapter 3 discusses the concept of computation and universal computing machines as relevant in theoretical computer science and explains why cognition should be viewed as a computation. This is fundamentally different from the suggestion that computational processes (or computer simulations) can serve as a useful metaphor or analogy for explaining cognitive phenomena. What is claimed is that computations performed on contents of internal representations do model the processes responsible for cognitive behaviour.

This view requires that computational processes be 'strongly equivalent' to the processes that actually occur in the brain. Chapters 4 and 5 discuss the constraints this requirement places on the functional architecture and specify two criteria for investigating possible structures for functional architecture. The first criterion is called complexity equivalence which needs, for two processes to be strongly equivalent, that their resource usage should be the same function of the characteristics of inputs. The second is that of cognitive impenetrability which requires that aspects of functional architecture cannot be altered by changing the semantic content of representations; that is, the goals and beliefs of the subject.

After completing this framework for a computational view of cognition, chapters 6–8 discuss certain aspects of the brain that seem to be non-computational in the sense that they do not involve any inference or reasoning. Chapter 6 is devoted to a discussion on perception and shows why totally non-computational approaches like Gibson's direct realism have many pitfalls. Chapter 7 describes the symbol structures and investigates the use of analogue structures *vis a vis* the functional architecture. Chapter 8 discusses the problem of mental imagery, probably the hardest phenomena to explain through a computational view point. The author suggests that, by itself it is not inconsistent with a computational view point because these tasks can be used empirically to constrain the functional architecture.

Finally, in chapter 9 the author sums up his approach and raises many interesting questions about what aspects of the functioning of brain are amenable to analysis in this framework. He admits that there are interesting aspects of the brain that fall outside this type of cognitive science.

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Analytic methods in the analysis and design of number-theoretic algorithms by E. Bach. The MIT Press, 28, Carleton Street, Cambridge, Massachusetts, 02142, USA, 1985, pp. 45, $ 17.25. Indian orders to Affiliated East-West Press Pvt. Ltd., 6, Roselyn Gardens Apartments, 20/1A, Barnaby Road, Madras 600 010.

Any high school student encounters the two problems of factoring and primality testing in the mathematics curriculum. The student is told about prime numbers and composite numbers, factorisation of integers, determination of g.c.d. and l.c.m. and perhaps the unique factorisation theorem for integers and the sieve of Eratosthenes. A college graduate, even one who is trained in the mathematical or engineering sciences, has no further idea about number theory and its consequences, except perhaps a few anecdotal sidelights about Fermat's last theorem, Goldbach's conjecture, or the number 1729. But, everyone has a vague feeling that number theory is an ancient, exquisite, and hard subject, and that problems in number theory have attracted the interest of some of the great mathematicians of the past such as Fermat, Euler, Legendre, Gauss, Jacobi, and Ramanujan. Much of what has been done recently has its roots in these early works.

In recent years there has been a spurt in research and pedagogical publications in number theory and its applications, thanks to two significant developments in computer science, concerning complexity of computations and public-key cryptosystems. The monograph under review is another excellent publication which makes excursions into the enigmatic lore of number theory and highlights the interplay between number theory and practical computing. This thin monograph is a reproduction of the author's Ph.D. thesis written at the University of California, Berkeley. The thesis has won the ACM Distinguished Dissertation award in 1984. Bach's two contributions are: (a) a 'quick' method of testing primality, and (b) a 'quick' method for finding 'large' prefactored (composite) integers.

To a computer scientist all number theoretic computations, basically, comprise a suite of computational algorithms for multiprecision arithmetic — the cost of a multiprecision multiplication of two n digit integers is about $(\log n)^2$ times the cost of a single-precision multiplication of the same integers; g.c.d.; multiplicative inverse of units in Z_n; exponentiation by successive squaring (mentioned in the ancient Indian text, *Chandha-Sutra* of Pingala, C. 200 B.C.) and operations in polynomial rings. In particular one computes x^t in Z_n at a cost of $\log t(\log n)^2$ single-precision operations.

All these algorithms are termed 'good' (efficient) since the cost of computing is bounded by a polynomial in the length of the input, and 'deterministic' since the answers output by these algorithms true with certainty. On the other hand the problem of finding a quadratic non-residue modulo a prima p is not known to have an efficient deterministic algorithm. However, it is easy to 'verify' whether a given x is a quadratic non-residue modulo p, using Euler's criterion $x^{(p-1)/2} = -1 (\text{mod } p)$, in $0((\log p)^3)$ steps. Now, for $p > 2$ half the integers in $\{ 1,.., p-1 \}$ are non-residues and we can find a quadratic non-residue by a probabilistic algorithm simply by trying successive values of x chosen independently and uniformly at random from $\{ 1,.., p-1 \}$ until one satisfies the condition.

One of the central questions in number theoretic computations is whether there are polynomial-time algorithms (perhaps, probabilistic), which for an odd integer $n > 1$ can

(i) factorise n, if n is composite
(ii) find a verifiable proof if n is prime.

The running time of these algorithms is thus required to be proportional to a power of $\log n$. While the promise of a positive answer to (i) appears to be bleak, the situation concerning (ii) is brighter.

There are the probabilistic tests of Solovay and Strassen, and Rabin which provide a strong guarantee for primality in $0((\log n)^3)$ time. These algorithms work by applying pseudo-prime tests a sufficient number of times. Deterministic algorithms were recently developed by Adleman, Pomerance and Rumely, and Cohen and Lenstra. These are of 'near' linear complexity, *i.e.* of $0(\log n)^{c(\log\log\log n)}$. These are based on generalized pseudoprime tests followed by sieving to restrict the set of possible divisors to small sets. Earlier, in 1976, Miller developed a simple polynomial-time primality test, by combining a strong pseudoprime test with a $0((\log n)^2)$ bound due to Ankeny on the least quadratic non-residue modulo n. This last result was, however, conditional to the assumption of Extended Riemann Hypothesis (ERH). In view of this bound, the complexity of the algorithm is $0((\log n)^5)$.

The task addressed to by Bach in this work is obtaining a good estimate of the implied constant in Ankeny's bound. Bach shows, by careful number theoretic estimates, and insightful arguments on the connections between the ERH and bounds on least quadratic non-residues, that the constant is 2. He develops asymptotic estimates, explicit bounds and bounds for specific modulii. He supplements these elegant, but tersely presented, results with computational comparisons of actual values of least quadratic non-residues and the values suggested by the bounds. The ERH-based estimates appear to be conservative.

The second half of the monograph is on the generation of uniformly distributed integers x, $N/2 < x \leq N$, for a given integer N, and having known factors. The method is based on applying repeatedly (about $\log N$ times on an average) the primality testing algorithm on integers 'chosen' from successively halved ranges. The meat of this chapter is in showing that the recursive algorithm indeed generates a 'uniformly' distributed integer. The results are derived using elementary probability theory and estimates from analytic number theory. The deterministic algorithm is of complexity $0((\log N)^6)$.

The author adopts a refreshing and illuminating style, offering intuitive explanations in a capsule form. He deduces his estimates of constants and complexity bounds by building an edifice of 20 lemmas and 11 theorems, all in a space of 41 sparsely printed pages. Needless to say the reader is expected to have a modest background in complex analysis, probability theory, analytic number theory, and elements of abstract algebra. In addition to the significance of this work, this monograph is an outstanding illustration of

succinctness, clarity, and beauty in mathematical writing. It would be a valuable guide to doctoral candidates in theoretical computer science and mathematics.

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