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VLSI Engineering

Beyond Software Engineering

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Praface

Many computer applications have come to have a complexity far beyond the capability of computer hardware currently available through commercial vendors. What is called the "software crisis" comes from an almost desparate effort to fill this growing gap by software. Software engineering is aiming at easing the crisis by providing various disciplined software tools and methodologies, and has been partially successful in filling the gap.

This volume is the result of our effort to go beyond the software engineering approach. Our goal is to remove the gap rather than fill it by cost effectively building application processors in hardware. Examples of the concepts, disciplines, methodologies, tools, architecture, design and implementation needed for such application-oriented computers are presented by leading experts invited from related technical areas. VLSI (very large scale integration) is the hardware technology which can easily cope with any degree of complexity normally expected in an application.

This volume focuses on VLSI-related engineering as it is used to produce application-oriented computers. This focus is expected to give further technical direction, integrity and uniformity to the papers. This VLSI engineering approach can lead computer technology beyond software engineering, and hence can contribute to overcoming the software crisis.

In Chapter 1, the authors compare software and hardware (especially VLSI) from the viewpoint of design processes. It clarifies similarities and differences of their structures and tools, giving improved insights into approaches beyond software engineering through VLSI. The basic framework is given to develop advanced systems step-wise starting from software requirement specification down to customized VLSI silicon chip design.

Chapter 2 reports the development of various advanced architectures which includes 5th generation computers, object-oriented architecture and tightly coupled network architecture. The continuing rapid progress of VLSI technology is beginning to make possible to build very large object-oriented, highly parallel computers and special purpose machines.

Chapter 3 first addresses the problem of optimal implementation of a class of computational processes. Specifically, it identifies computational structures that are well suited for VLSI implementation in the form of what are called systolic algorithms. Application includes computations in pattern matching and error-correcting. Next, a class of high speed algorithms by combinatorial circuits and their hardware implementation methdology is proposed in terms of the VLSI algorithm called a Bus Connected Cellular Array. The complexity theory of hardware algorithms is surveyed in connection with the present topic.

One undisputed consensus on the recent trend on computing is the need for highly parallel computing. Central problems associated with highly parallel computing include optimal architectures for a given class of problems, optimal network configurations among processors and effective methods for algorithm design and programming. Due to the increasing complexity of VLSI circuits, design and testing problems are becoming more and more important. There are two possible approaches to

these problems which are discussed in Chapter 4: (1) To extend the traditional logic design and testing methods to meet the requirements of VLSI circuits, and (2) to utilize techniques developed in the area of software design and verification. The second approach is a good example of a bridge between software engineering and hardware engineering. First, the second approach is discussed in connection with two important topics: one is with parallel computation and the other is with the logic programming language PROLOG. Graph-based design specification of parallel computation is studied and a new method is proposed. On the second topic, it is explained how PROLOG is used to write input and output assertions as well as hardware specifications. Next, a practical approach to VLSI verification and correction is briefly summarized. At the end of Chapter 4, a new VLSI design method is proposed. A flowchart specification is translated into a network of interconnected boxes and local transformations are applied. This method can be used to transform an implementation from one form into another.

Chapter 5 deals with VLSI implementation of database systems and document image processors: (1) A hardware file system for efficient database processing with reduction of communication cost among VLSI circuits, (2) Highly parallel database machines focusing on search operations, (3) A picture database machine with interconnection architecture among a large number of VLSI chips and chip architecture, and (4) Methods and requirements to produce high resolution document image processors which exploit VLSI technology. The first part discusses an approach in which a data storage device processes data, and a single circuit performs various operations. Efficient processing is attained by the principle of partitioning (division of the data to be processed into subsets and parallel processing of these). The second part describes principles of parallel database operations, comparisons of typical search methods, and the analysis of a search algorithm (parallel search trees). The third part presents a graph based interconnection diagram and PASCAL-like language to be used to support an extended relational calculus for describing data operations, and an algorithm to decompose the extended relational calculus into interconnection diagrams. The last part develops a new dimension to utilize customized VLSI technology. The case of a digital document image processor is intensively studied, and actual examples are illustrated.

Most of the authors have been invited from among the contributors to the 16th IBM Japan Computer Science Symposium on VLSI Engineering — beyond software engineering — held at Hakone, Shizuoka Prefecture, October, 1982. The editor is grateful to IBM Japan for its support in making the updated version of important papers available for this book.

Tokyo, Japan

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