BOYD C. PAULSON, JR.

COMPUTER APPLICATIONS IN CONSTRUCTION

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COMPUTER APPLICATIONS IN CONSTRUCTION

Boyd C. Paulson, Jr.
Stanford University

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ABOUT THE AUTHOR

Boyd C. Paulson, Jr., holds the endowed Charles H. Leavell Professorship of Civil Engineering in Stanford Unversity's Graduate Program in Construction Engineering and Management. He served on the civil engineering faculty at the University of Illinois in 1972 and 1973. He was also a Visiting Professor at the University of Tokyo in 1978, the Technical University of Munich in 1983, and the University of Strathclyde in Glasgow, Scotland, in 1990–91. He earned his B.S. (1967), M.S. (1969), and Ph.D. (1971) in civil engineering from Stanford University. He is the author or coauthor of two books and over 90 papers.

Paulson's research and teaching interests are primarily in computer applications in construction, including automated data acquisition, operations simulation, and automated process control. He has had numerous research projects in these and other areas sponsored by the National Science Foundation, the U.S. Department of Transportation, and others.

Paulson's professional activities include past chairman of ASCE's Committee on Professional Construction Management and the ASCE Task Committee on Computer Applications in Construction, past vice chairman of ASCE's Construction Research Council, and past chairman of the ASCE Construction Division Executive Committee. He was twice elected secretary of the Project Management Institute. He is a member of Tau Beta Pi, Sigma Xi, ACM, ASCE, ASEE, and the IEEE Computer Society.

His honors and awards include ASCE's 1980 *Walter L. Huber Civil Engineering Research Prize*, West Germany's *Alexander von Humbolt Foundation Research Fellowship* in 1983, ASCE's 1984 *Construction Management Award*, selection in 1984 as a *Distinguished Scholar* by the U.S. National Academy of Sciences Committee on Scholarly Communication with the People's Republic of China, the 1986 *Henry M. Shaw Lecturer* at the North Carolina State University, the Project Management Institute's 1986 *Distinguished Contributions Award*, 1990–91 faculty research and teaching scholarships from *The Fulbright Foundation* and *The British Council*, the 1992 *Kudroff Memorial Lecturer* at Pennsylvania State University, and ASCE's 1993 *Peurifoy Construction Research Award*.

To Jane, Jeff, and Laura

PREFACE

Computer knowledge has become increasingly essential to the success of today's construction engineers and managers and will become even more so in the future. The question for those going into this field is how best to acquire an understanding of this subject that will be most useful in construction practice.

THE NEED FOR THIS BOOK

In colleges and universities, even three decades after the importance of the subject began gaining recognition in professional construction engineering and management programs, the most common way of including computer studies in the curriculum still seems to be a class in computer programming. When the subject is taught well, students can acquire a general knowledge of computer science or data processing and learn how computer methods can assist in structured problem solving. Too often, however, the students just learn the rules and syntax for a programming language they may never use again and apply it only to the rote solution of abstract problems. It is no wonder that for many people their introduction to computers was an experience they would just as soon forget, and that later in their careers they become wary when anyone talks about applying computers to solve problems related to their job environment.

I have taught computer applications in construction for over 20 years and have grappled with the questions of what to teach and how to teach it to construction professionals. Like many, I began by teaching computer languages and focused on construction mainly via examples and assignments to program solutions to simple construction-oriented problems. Especially in the days of card-fed mainframe computers, the results were hardly worth the effort, and I fear that I too left many students disillusioned by the ordeal of late nights at the computer center debugging their way through the minutia of programming language syntax. Over time things improved, first with interactive minicomputers, whose online editing capabilities and quick-response program compilers at least took some of

the drudgery and delays out of the homework, and they improved even more as microcomputers made the tools accessible in our own teaching environment. Things got much better still when programmable spreadsheets and databases came along in the early 1980s, because such tools made the actual programming simple enough that students could focus more directly on developing professional-looking and useful construction applications. But as a teacher I still did not feel as satisfied as the students seemed to be with the course.

The problems that remained were how to select the most useful body of computer knowledge for *construction*, not computer science, and to find a text to support that goal. The problem of selection is that there is now far more to be learned about rapidly evolving construction applications than can fit into a college course or a book, so one must strike a balance between fundamental concepts and useful applications. The problem of a suitable text has dogged me for all of the years I have taught my course. Every year or two I would select a new text, mostly from those intended for introductory software engineering or data processing courses, but too little of their content seemed relevant to construction from the students' and practitioners' viewpoint. There have been a few attempts at books oriented toward computer applications in construction, but those available seemed to date from the earlier era when teaching a language—or more recently a few application packages—with a few construction-flavored examples, was viewed as sufficient.

This book is a result of my years of struggling with the basic questions of how to teach computer concepts and applications in a way that is most useful to students and practitioners in construction. It follows a formula that has achieved considerable success in my own teaching in recent years, and I have wanted for some time to write it down in a way that might help others. A recent year's sabbatical in Scotland gave me the opportunity and time to make a good start toward achieving this goal.

STRUCTURE AND CONTENT

A quick glance at the table of contents shows the method I have chosen. There is a logical progression in the overall structure, reflected as Parts I to VI, but within the major applications-oriented sections (Parts IV and V)—about 60 percent of the book—chapters are modular and self-contained. One can pick and choose as desired.

Inevitably a book has compromises. In selecting and ordering the material, I have tried to make my compromises in favor of entry-level students or practitioners who would like to start with little or no prior background in computers—no programming skill or computer science course is needed as a prerequisite for this book—and reach a level where they have a sound grasp of how computers are being used in construction today and know better how to go about acquiring or developing useful applications for the future.

Part I begins with an overview of the subject. Chapter 1 shows why computer technology has been such an important force in changing the way the construction

industry does business and why it is strategically important for companies in the future. For overall perspective, Chapter 2 offers a quick tour through a wide range of construction applications, many of which will be examined in more detail in the eight chapters that make up Parts IV and V.

Part II provides a background introduction to computer technology. The focus is on practical knowledge and basic terminology needed by construction professionals in making acquisition and development decisions that involve computers. Chapter 3 focuses on hardware topics, including the central processor, peripheral storage, input and output devices, automated data collection and control systems, and computer communications. Chapter 4 concentrates on system software and application development software, plus information storage in files and databases. These chapters sufficiently define the basic concepts and terminology for the level needed in later chapters. Readers having prior computer experience or course work might wish just to skim through them.

Part III is analogous to the planning and design stages of a construction project—stages that should take place before the equipment, materials, workers, and methods of construction are employed to construct the project itself. Chapters 5, 6, and 7 deal with the analysis and design of applications and with methods and concepts that can more successfully guide development and implementation. Only the basic and more practical aspects are covered here, but there is enough information to improve the success of planning and acquisition decisions for computer applications.

Part IV, in Chapters 8 to 11, deals with the development tools—the materials, equipment, and methods, if you like—that are commonly used by people to create construction applications today. They include programming languages, spreadsheet and database packages, and new methods based on artificial intelligence and knowledge-based systems. Although these four chapters are not a substitute for the specialized textbooks that are available on each tool, the basic concepts are introduced and illustrated with practical examples and problems that show a variety of ways in which these tools can effectively help create useful construction applications.

Whereas Part IV deals with general development tools that can produce a wide range of construction applications, Chapters 12 to 15 in Part V introduce application packages more specifically focused on certain types of construction problems: estimating, planning and scheduling, accounting and cost control, and simulation. Each of these chapters includes at least two packages to demonstrate different aspects of the application's spectrum.

The final chapter of the book, in Part VI, explores trends in an area that is literally creating its own future! Computers have already had a major impact on the ways that companies, projects, and people work, but they are increasingly going to be changing the structure of the construction industry itself. Already, projects are being designed as electronic three-dimensional models of reality, with the ability to simulate very realistically the types of production problems that might be anticipated—and avoided—in the field. With the advent of expert systems, automated machines, and even robots, we are fairly close to computers doing parts

of the field work themselves. Increased computer-based integration of design, construction, and facility management will continue to change the relationships among design consultants, contractors, and owners alike. Chapter 16 briefly examines technologies behind these trends so that the reader will have basic concepts and terminology needed to follow the changes that will be taking place.

HOW TO USE THIS BOOK

Taken as whole, this book provides the reader with a sound background on what is going on with computers in construction, and reading for a deeper understanding will enable construction engineers and managers to make better decisions in acquiring or developing useful construction applications. However, nothing beats hands-on experience, so in addition to studying this book it is highly recommended that the reader try some of the applications and solve some of the problems on a computer. Of course, whereas the book itself assumes no prerequisite courses, use of a computer, development tool, or application package will require access to the relevant manuals or help from a colleague who can quickly introduce a few fundamentals. Do not be daunted by the thick bulk of typical software manuals, however, since one can become productive with much if not most software of the type used in this book with only a brief tutorial (whether online, by following a manual, or with a teacher) and can thus acquire enough knowledge to do the types of exercises given in this book.

Particularly in the chapters that make up Parts IV and V, the development tools and several of the application packages that have been selected for illustration are those that are often used in colleges and universities and in construction companies. Most are also fairly economical to buy, and even some of the commercially more expensive ones are made available to colleges and universities at substantial discounts or even as grants. All of the commercial programs used for illustration in Parts IV and V of this book are available for readily accessible and easily used microcomputers. Furthermore, I have made a deliberate effort where practical to select a tool or application in each chapter for Apple Macintosh computers, which are commonly used in colleges and universities for their ease of use in teaching, and for IBM PCs and compatibles, which are also used extensively in academia and dominate the construction business world; PCs further account for most of the commercial application packages in construction.

This book, combined with exercises on microcomputers, is designed for a one-quarter course of four credit hours or a one-semester course of three credit hours. It would be most suitable for upper division undergraduates or master's degree students who already have a working knowledge of some of the construction application areas (estimating, planning and scheduling, etc.). Where time is more constrained, the material in the book is modularly packaged so that a teacher can easily skip chapters out of Parts IV and V as desired and can also focus within them on the examples most pertinent to the type of computer and software being used to supplement the reading. Similarly, if the curriculum already includes a basic computer programming or data processing course, readers might skim or

skip Part II. However, do not skip Parts I and III, since they are fundamental. Part VI is the most speculative and could be included as time permits or be left to independent reading.

For a practitioner to get the most out of this book, he or she should ideally already have some familiarity with the type of microcomputers found in offices and job sites, including the use of one or two packages such as spreadsheet, database, or scheduling programs. Even though you may not have the same software as that used for illustration in this book, the types of examples and exercises given here could be done using almost any similar software. A few hours spent using the office computer at lunch or after work would considerably deepen your understanding and provide a real personal satisfaction in studying this subject. The design and implementation of applications on computers provide rewarding opportunities for personal creativity, and once implemented the results of your own ideas can also take much of the tedium out of routine construction engineering and administrative chores.

Within this text, computer terms that may not yet be familiar to the general reader are presented in boldface italic type on their first usage. Besides their definition in the text, these terms are also defined in the glossary of computer terms in Appendix B.

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I began writing this book on a cold November night in Bearsden, Scotland, not far from Loch Lomond. I was there, at home with my family, through the good fortune of my 1990–91 sabbatical at the University of Strathclyde in Glasgow. That year for thought, research, and writing was granted to me by the Fulbright Commission, the National Science Foundation, and The British Council. I am deeply grateful to them all for that opportunity.

My hosts at Strathclyde were Professor George Fleming and Professor Iain MacLeod, who extended their kind and gracious Scottish hospitality during our stay and made that year a wonderful cultural experience for our family. In that environment I was able to get about halfway through the first draft of the manuscript. More importantly, I had freedom from day-to-day academic pressures—freedom that enabled me to think through the whole concept of the book that you now have in hand.

After returning to Stanford, it took me two and a half more years of weekends, vacations, and seemingly endless evenings to being this book to completion. It takes an enormously kind, supportive, and loving family to make that much time possible, and to them I am most grateful of all. I cannot restore to them all that lost time, but they can take some satisfaction if you, the reader, find this book useful. It is their book, too.

Several people gave generously of their time to help me with this book. Ray Levitt was my sounding board for Chapter 11, and his research is reflected in the safety example. Mohan Manavazhi prepared two of the figures in Chapter 8. Hossam El-Bibany wrote the Prolog program in Chapter 11. John Fletcher and Erv

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Finally, I salute my students from the past two decades of CE 243 at Stanford. Too often, as we struggled together through rapid changes in computer technology—including some things that did not work very well—they ended up spending too many "all nighters" with computers. To them I confess that the course deserved its reputation for excessive demands on student time. Next time it is definitely going to be easier than before!

Boyd C. Paulson, Jr.

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