

FARID M.L. AMIROUCHE



UTAH/MIT
DEXTRIOUS HAND

**COMPUTER-AIDED
DESIGN AND
MANUFACTURING**

Computer-Aided Design and Manufacturing

Farid M. L. Amirouche

University of Illinois at Chicago



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Preface

With the advent of today's computer technology, we are experiencing a new twist in the way we teach our courses and especially in the manner we educate students on the topic of design. Today, our engineering graduates find themselves facing greater responsibility and challenges in making decisions on companies' product design and manufacturing. Students in most cases need to have the ability to interact with the so-called CAD/CAM systems and understand the basics of the process of design and manufacturing in order to communicate better and be more productive.

The intent of this book is to bring together in one volume the most important areas of design, analysis, and manufacturing in which computers and computer graphics have had a great impact in the past decade and will continue to do so in years to come. The book content is tailored for advanced juniors and seniors and first-year master's degree students. The book should appeal to a large body of engineering fields, especially mechanical engineering. The emphasis in the entire book is on the integration of three disciplines: CAD, CAE, and CAM. Our future engineering students will find themselves more active in all stages of design. This will be possible only with the integration of those disciplines and the blending of man and machine to meet tomorrow's challenges and highly competitive markets. In this book, both design, including analysis, and manufacturing are given equal coverage. Instructors will decide which chapters to use according to their school curriculum. Using the book out of sequence will in no way affect the continuity of the material presented. As a matter of fact, some chapters, such as Chapters 1 and 2, could be assigned as outside reading. Chapter 3 explains the basic concepts of design and shows the effectiveness of computers and computer graphics in today's design process. Illustrative examples are given to stimulate the interest of stu-

dents in the assigned projects. Chapter 4 is unique; in a sense, it serves as the basis to computer graphics. The derivation of transformation matrices and description of curves encountered in engineering are illustrated through numerous examples. Chapter 5 provides a basic understanding of solid modeling and its integration in today's design and manufacturing. In Chapter 6, the finite-element method is introduced, emphasizing the simplest concepts of mechanics that students learn at the sophomore and junior levels. Applications of CAD/CAM technology are provided in Chapter 7. The manufacturing part of the book is covered in Chapters 8 through 14.

Chapter 8 gives a general introduction to manufacturing. The evolution of manufacturing processes from manual to CNC and DNC machines are fully explained. The programming aspects of CNC machines through APT are presented into two chapters, namely 9 and 10. A complete description of APT geometry and motion statements are described making use of simple yet practical examples. Robotics Technology is introduced in Chapter 11 and 12. These two chapters provide the most comprehensive description of robotics today and their industrial applications. The economics of robots and their purchase justification as well as payback returns are presented for the first time through meaningful exercises. To extend further our understanding of Computer-Aided Manufacturing, selected topics on Group Technology, work cells, and process planning are covered in Chapter 13.

New concepts of Computer-Integrated Manufacturing (CIM) are presented in Chapter 14. This includes a state of the art architecture of CIM and its implementation. The book's last chapter (15) presents some views as to what factors should be considered when purchasing a CAD/CAM system in order to remain competitive.

It is important to note that a full coverage of matrices is presented in appendix A. Many of us teaching a course in CAD/CAM might need a week or two to review matrices. This appendix is very helpful to students. Appendix B gives a listing of a 2D finite element truss developed based on concepts presented in Chapter 6. The intent of this appendix is to give students a platform where they can modify the program input/output to better interact with CAD in general.

A Glossary of CAD/CAM terminology is provided at the end of the book.

The presentation in this book takes a problem-solving approach to the topics, guiding the students through a series of worked-out problems. The book is an outgrowth of years of teaching and research in CAD/CAE/CAM at the University of Illinois at Chicago and the University of Cincinnati. This includes videotaping the course called Introduction to CAD/CAM offered to off-campus engineering students in the Chicago area.

Depending on the students' background and the teaching philosophy, a laboratory class could be introduced to complement the course. The author advises that students be introduced to a CAD graphics package to learn the parallels between theory and practice.

Each chapter of the book ends with a set of problems and assignments written to guide the student through the course. In Chapters 4, 5, 6, 9, 10, and 13 the homework problems could be done in a CAD laboratory where students will get some practice using CAD/CAM workstations or simply PCs equipped with the appropriate software.

This book is written on the assumption that students have had no prior exposure to CAD/CAM; hence the terminology is kept simple and stimulating. Clearly, in a subject as broad as CAD/CAM, not all the subjects can be included. But I believe that if the students are engaged on a number of the projects outlined in this book, they will absorb the materials better.

The author expresses his appreciation for the valuable input from the University of Illinois at Chicago students who took his course Introduction to Computer-Aided Design and Manufacturing (ME 347). I am indebted to the reviewers for their useful suggestions and comments which have undoubtedly enhanced the quality of this book: especially Dr. Ronald L. Huston, my all time friend and colleague, University of Cincinnati; Dr. Tienko Ting, University of Bridgeport; Dr. Dave Janak, University of Cincinnati; and Dr. Musa Jouaneh, University of Rhode Island. I am equally grateful to my students Mr. Steve Tai and Mr. Tarun Arora for their dedication in preparation of parts of the manuscript and illustrations. Without their help this book wouldn't have been possible. I would like to also thank Mr. Nandan Mehta for his efforts. For those who helped contribute to this book by providing me with pictures of their company products, many thanks—especially Ms. Julie Carroll and Ms. Kristine Von Elm from the Center of Engineering Design, University of Utah; Ms. Ann Smith from the ABB Robotics; my friend Mr. Mark Lawry from SDRC; Mr. Vipul Kinariwala from EMRC; Mr. Tom Cole, Public Relations from Boeing Corporation; Mr. Peter May, Algor Inc.; Professor Bob Mabrey of Tennessee Technical University; and Mr. Doug B. Carter, Cincinnati Milacron. I would also like to extend my appreciation to Mr. Peter Zurita for doing an excellent job in editing the book and my friend Mr. Doug Humphrey for his continuous efforts in bringing this book to production.

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Sometimes we forget the most important people in our lives, those that are responsible for us being here today. For that I would like to thank my father Med Larbi and my mother Yakout for the love they gave me and the appreciation they taught me about education. For my kids, Larby and Anissa, I love you very much.

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ABOUT THE AUTHOR

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chapter 1

Historical Perspective on Digital Computers

1.1 INTRODUCTION

In this era of high technology and computer sophistication, it is inconceivable to talk about computer-aided design and computer-aided manufacturing without first looking back to see where it all began. The essence of computing began in the early 1940s. Though the issue of who first invented the “stored-program computer” is controversial, its history can be traced back to ENIAC (Electronic Numerical Integrator and Computer).

1.2 HISTORY OF THE COMPUTER

Throughout history, humans have always attempted to design and invent mechanisms that would ease the burden of their labors. Until the nineteenth century, these mechanisms could help only with physical work. Not until late in that century were mechanisms designed to assist with mathematical work: computers developed to perform addition and multiplication. These adding machines (also known as third-generation computers) were built from gears, springs, and other mechanical parts. They were limited in functions but did not make mistakes in operations and were faster than calculations done by hand. Complex electromechanical computers were later developed to perform advanced calculations. They used a binary (base-2) logic architecture to symbolize entities and functions. For logic operations, 1 represented a value and 0 represented no value. In a binary representation, addition, subtraction, multiplication, and division were easily performed. For example, to calculate the

values 10 and 2 using the four math operators (addition, subtraction, multiplication, and division), we must convert the values to binary numbers (see Appendix 1-1 for further details):

$$(10)_{10} = (01010)_2$$

$$(2)_{10} = (00010)_2$$

To perform addition:

$$\begin{array}{r} 01010 \\ + 00010 \\ \hline 01100 \end{array} \quad (01100)_2 = (12)_{10}$$

To perform subtraction:

$$\begin{array}{r} 01010 \\ - 00010 \\ \hline 01000 \end{array} \quad (01000)_2 = (8)_{10}$$

Mastery of the binary system made the modern computer possible.

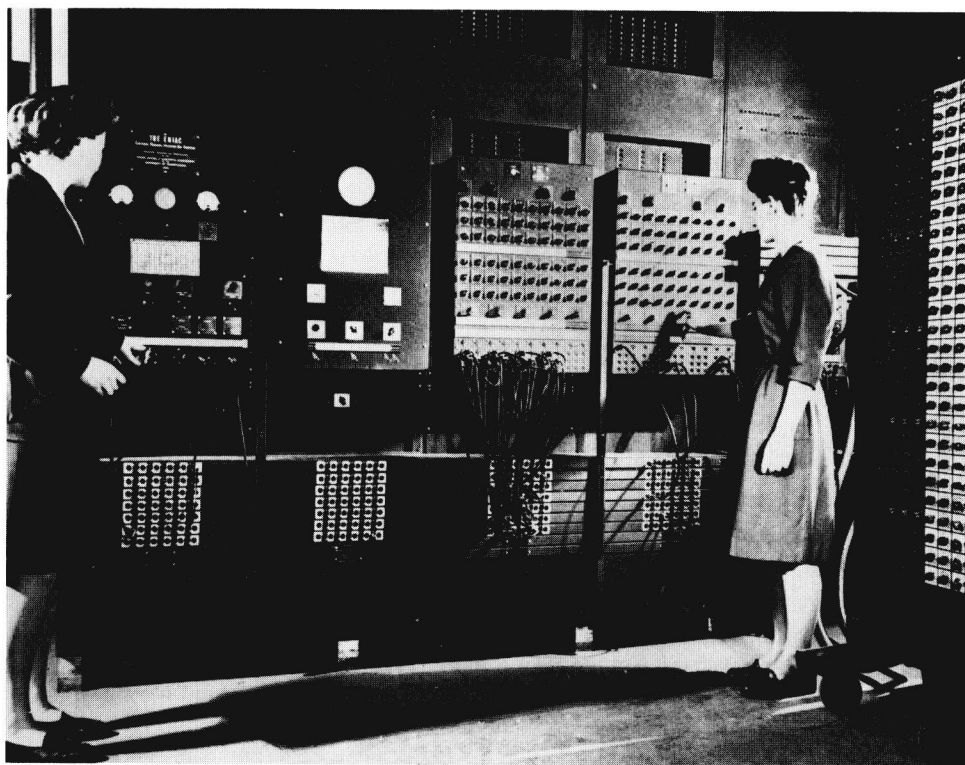


Figure 1.1 General view of 'ENIAC', the 1st general purpose Electronic Calculator (Courtesy of UPI/Bettmann newsphotos).