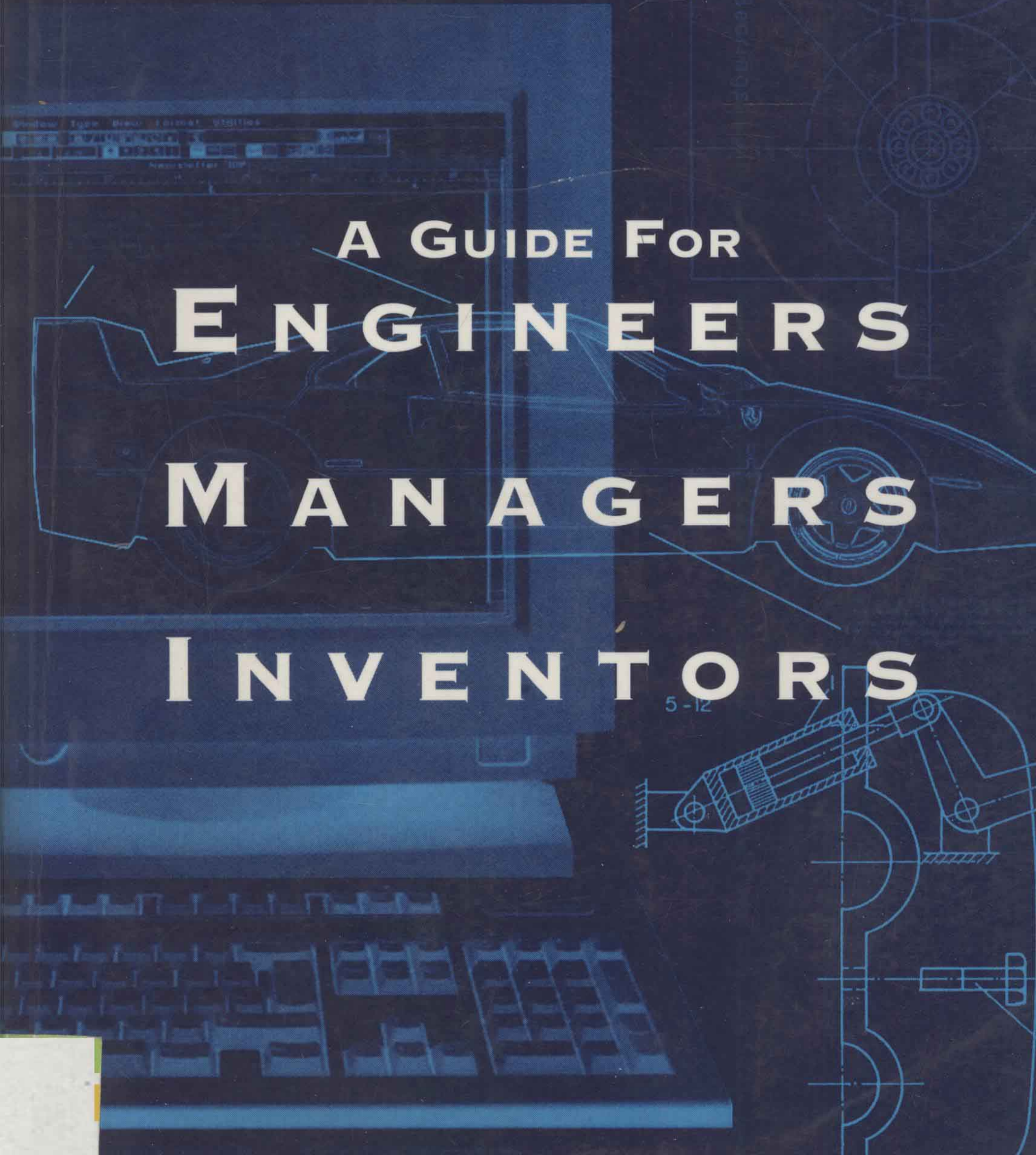
COMPUTER-AIDED CREATIVITY



A GUIDE FOR ENGINEERS MANAGERS INVENTORS

BEN-ZION SANDLER

COMPUTER-AIDED CREATIVITY

A GUIDE FOR ENGINEERS MANAGERS INVENTORS

BEN-ZION SANDLER, PH.D.

THE HY GREENHILL CHAIR IN
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BEN-GURION UNIVERSITY OF THE NEGEV, BEERSHEVA, ISRAEL

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Preface

The main purpose of this book is to improve the reader's inventivity.

To give him (or her) *new methods* to link the human mind, the computer and technology in what I hope will be a unique and useful manner. The potential of these methods and approaches can go beyond engineering into the fields of R & D, product development, marketing product evaluation, etc. Hopefully they will prove useful in medicine, genetics, psychology, and other fields.

We wish to create a kind of selective filter that helps us separate the ideas which have a better chance of being successful from those doomed to failure: how to use data bases to make such judgment calls, how to use the computer for simulation of intuitive thinking.

There is a saying that, "Medicine is a science, but the practice of medicine is an art." Like medicine, engineering is based on both intellectual activities. The conceptual stage of design, being close to an art, is less amenable to computation than are later stages. Nobody knows exactly how human brains work in solving creative problems. It is clear that the process is not one of simple trial and error. The duration of a human being's life is hardly enough to solve every creative problem by such an approach.

Computer Aided Creativity picks up where a previous book of mine, *Creative Machine Design* (1985, Solomon Press), leaves off. It teaches techniques to find formal ways of describing thought processes applicable to technical fields. I propose some principles to enable creativity in various domains of conceptual design to be simulated.

To be creative is to be curious. How can we compel the computer to express curiosity, to ask questions? The process of satisfying one's inquisitiveness can be considered, to some extent, an optimization process. It can be considered analogous to the process of seeking minimums (or maximums). We ask the computer to answer such questions as, "Is *a* bigger than *b*?" Obviously, the computer can answer such questions easily. (What the computer cannot do is to feel the *necessity* to ask such questions.) *Computer Aided Creativity* considers some examples where it is possible to simulate creativity by such optimization approaches.

The beginning of any design process is preceded by a mental image of what must be designed. The designer first has to "visualize" the main principles and concepts underlying his design. This preliminary design stage occurs before the stage at which well-known modern computer-aided design and graphics methods can be used. The preliminary stage of conceptual design includes elements of art.

What can help at this design stage is effective organization of thinking, knowledge of the basic "laws," principles, and approaches that govern the process of technical creativity, and some computerized simulation of these "laws." This latter aspect constitutes the subject of this book. Such a process does, of course, not replace the engineer's ingenuity. The computer-aided techniques in conceptual design that are considered in this book serve the same role as handbooks and encyclopedias play in conventional creative activities. The algorithms presented here will help save time and effort in searching for concepts, as do handbooks, diagrams and tables.

Taking into account the fact that readers who are familiar with programming are less informed about the peculiarities of the design process and vice versa, I have put the accent in this book on the approaches to conceptual design.

The book is divided into six chapters: Chapter I, *The Philosophy of Computerized Creativity,* discusses computer-aided activities in the design process, that is, what *can* and *cannot* be anticipated from the computer.

For example:

A. You can "teach" computers how to help search for technical concepts.

B. You can organize computers to aid in the miraculous creative processes of imitation of creativity, imitation of intuition, etc.

C. You can even use computers to simulate the discovery of Kepler's laws, how to simulate the discovery of Ohm's Law, and to simulate the discovery of other earth-shaking laws in the history of science.

Chapter II explains several morphological approaches to creation of new technical ideas. The application of these approaches expedites the process of evolving original concepts. Formalization of these approaches is described, opening the way for computerized simulation.

Chapter III describes saturation, rehabilitation, analogy and inversion principles in creative thinking. "Recipes" designed to utilize the principles and the algorithms depicting them in a formal manner are included; these facilitate computerized and manual simulation to a certain extent.

Chapters IV and V deal with simulation of intuition and association thinking techniques. A stochastic description of these techniques illustrate how they can be utilized by computerized or manual simulation.

Chapter VI is devoted to the use of PROLOG language, the specific properties of which permit the building of algorithms for the extraction of new concepts from a data base. A triad method of solving technical problems (proposed by Dr. Altshuler) is briefly described and a simulation algorithm is presented.

Every statement is illustrated with numerous examples chosen from the history of technical development and from my own experience. The examples were chosen according to the following criteria: 1) They are simple to explain and understand; and 2) They belong to well-known domains (at least to those involved in technical work). To make the explanations easy to understand, I have followed the principle "qui vidit bis legit" (he who sees, reads twice) and have therefore used many graphical illustrations.

The examples also serve as a source of information about how others have solved their problems. The more examples, the more chance of finding either the desired solution or the necessary method for finding it. In addition, by studying the examples the reader will learn what constituted the failures and successes of his predecessors.

Almost every paragraph is accompanied by questions and/or exercises. Some of the exercises are provided with answers. The book also includes appendixes containing programs simulating the described techniques. The example programs are long enough to illustrate the idea of the algorithms. I hope that by substituting appropriate data into the program examples, the reader will be able to get the feeling of how the proposed algorithms work and to test them for various applications. Of course, the reader is free not to consider them.

Almost every subject is considered within the following framework:

— Objectives of the chapter or paragraph

— Definitions of rules, principles, approaches, methods
— Examples illustrating how to use these rules, principles, etc.
— Discussion and explanation
— Algorithm, its formalization and how to use it.

It seems to us that regardless of the kind of occupation, profession, job titles, or maybe even age, many people are curious to learn something about innovative techniques, especially ideas on computerizing the process of innovative thinking. So we hope this book will interest design and general engineers, industrial and other profile researchers, math/science graduate students, college professors, beyond engineering intellectuals, marketing, product and manufacturing people, etc.

In conclusion I dare to quote one of the reviewers appraising the manuscript by saying:

"I believe *Computer Aided Creativity* has a major exalted mission that has real potential. In fact, this approach can be paralleled to (TQM) Total Quality Management methods. American needs better ways to arrive at more competitive product designs, polished existing products, and processes that have undergone precise scrutiny. CAC offer futuristic methodologies that can make this possible."

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I express my deep appreciation and respect to my colleagues at Ben-Gurion University of the Negev. Special thanks are due to Mr. K. Winnikof, who wrote and edited the programs (Appendixes III-X) and thus illustrated the ideas in computer language.

I also thank students O. Shai, N. Ozer and J. Halu for their help in demonstrating some ideas in the use of PROLOG and in simulation of associative thinking.

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This is my third book under the guidance and management of the Solomon Press. I am indebted to both Raymond and Sidney Solomon for their devotion, their graphic skills and professional handling of the complex tasks of the publishing process.

And last, my thanks to my family, to my wife and especially to my wonderful grandchildren, Eden, Maya and Shani, who made all these efforts worthwhile.

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"... our creativity outruns our capacity for anticipating the outcome of that creativity."
(Myhill, J., Some philosophical implications of mathematical logic. Rev. Metaphysics 6: 105–95, 1952).

1

The Philosophy of Computerized Creativity. What is This Book About?

You tackle a problem, your mind has run dry, you have a lot of other problems on your mind which interfere with seeing the whole picture clearly.

Why not ask the computer to help you, to free your mind for the main work?

Let the computer determine the existing possibilities which may be hidden by the versatility of your knowledge and thinking.

You will learn about:

— Some ways to "teach" the computer to help you in seeking technical concepts.

— How to organize the computer for aiding the miraculous process of your creativity.

— How the process of finding new ideas in technique can become formalized in some way.

This book is not about replacing the human brain with a computer terminal and screen.

1.1 FORMULATION OF CREATIVITY

"To create" is part of "to think." The process of invention, of seeking technical solutions, of the creation of new products, is a game with nature, in which nothing other than uncertainty and a lack of knowledge should daunt us. In this game, nature is an indifferent rather than a competing or helping partner. It may be said that we confront the unknown without a definite opponent.

Let us suppose that this process of invention or this game between man and nature takes place in the following stages:

1. The inventor has in his memory an abundance of different kinds of information. He does not necessarily know when he will have to apply his knowledge to seek a solution, but the wider the domains of his knowledge, the greater the chance he will have of hitting a "lucky" idea.
2. Irrespective of whether the inventor applies this information subconsciously, intentionally, or intuitively, he will use one or more of the following methods: systematic approach, morphologic approach, direct or indirect analogy, or inversion.
3. Once he has found solutions to his problem, the inventor will evaluate and compare the alternatives either intuitively or on the basis of certain "markers."

The question is, to what extent this procedure can be organized, formalized and perhaps utilized by a computer? The behavior of the computer is reminiscent of that of an insect. The insect is able to perform very complicated logical tasks, but is not innovative. Let us take the example of the bee. Although the bee does not have any scientific degrees or knowledge of optimization theory, it knows how to collect nectar and produce honey, and how to build a hexagon-based honey-comb. This insect, however, remains noncreative: when placed in a nonstandard situation, it becomes completely "illiterate." In contrast, man (who does not know how to produce honey) has created geometry and has defined the concept of polygons, including the optimal shape for the building block of the honey-comb—the hexagon.

Similarly, for millions of years the seasonal migration of birds has been controlled by a "navigation" technique which has not yet been elucidated. Some experts feel the sun and stars serve as indicators; others think the sea shores and other visual markers act as guides; still others have proposed a theory that magnetic sensitivity possessed by birds helps to orientate them. The point we wish to make here is that migrating birds are able to find their way even though they have no knowledge of geography, astronomy, or the theory of magnetism.

1.1.1. Example. "Geneticalgorithm" for the behavior of a wasp

Now let us write a "genetic program" for the behavior of an insect, say a wasp, when it comes into contact with an object—which may be food, a different kind of insect, or another wasp:

```
INSECT = Y
WASP MALE = WM
WASP FEMALE = WF
TEMPERATURE = T
SMELL = S
FOOD SMELL = SF
WASP SMELL = SW
A WASP MEETS AN OBJECT = A
WF MEETS WF = B
WF MEETS WM = C
WM MEETS WM = D
WM MEETS WF = E
IF A GO TO 50
50 IF (S–SF) 60, 200, 60.
60 IF (S–SW) 500, 70, 500
70 IF (A–B) 80, 300, 80
80 IF (A–C) 90, 400, 90
90 IF (A–D) 100, 500, 100
100 IF (A–E) 500, 110, 500
110 IF (T–20) 300, 600, 600
200 EAT
300 PAY NO ATTENTION
400 CURRY FAVOUR WITH WM
500 FIGHT
600 MAKE LOVE TO WF
```

Let biologists forgive us for this primitive and free interpretation of the wasp's life. What we have done is to write a program for a situation in which a wasp meets an insect, and on the basis of smell "decides" whether the other insect is a wasp or not. If "not" it fights, if "yes" it investigates the sex of the partner, and depending on one of possible four combinations

1. Male-male
2. Male-female

3. Female-male
4. Female-female

"decides" whether to ignore the other insect, to mate with it, or to curry favor with it. But if there is a strong smell of food (or of an insect that can be eaten), or a change in temperature, the sequence will be broken even when the other conditions remain constant. Modern science explains these phenomena in terms of innate instincts, genetic codes, or inherent abilities. Thus, nature's "programs" are designed to dictate the behavior or responses of millions of different kinds of animals in a relatively limited number of combinations of situations. In a situation which deviates from its "program," the animal becomes confused and cannot function instinctively, resulting (in the worst event) in death.

The human brain, in contrast, has inherited the ability to handle "nonprogrammed" situations: in addition to man's ability to act instinctively, he is able to create ideas, tools, and concepts. Let us try to understand what makes a particular action creative, while another action, even though much more complicated, is not creative at all. Why should a child putting one brick on top of another be creative, while a computerized robot assembling an electronic circuit be stupid and non-innovative?

We do not pretend to analyze here what creativity in general is all about. But when the subject under consideration is the computerization of technical creativity, we must define (at least in part) where the boundaries of creativity lie. Let us return to the creative child. What makes him innovative? It is his capacity for imagination, and for formulating and asking questions? Why is the formulation and solution of a simple problem (such as how much is 3 + 1) worth more than the computing of a differential equation by a computer following some program?

The computer does not possess curiosity, imaginativeness, intuition, or the ability to take initiative. We do, however, know of chess-playing computers, and chess is certainly a creative game. What then is the difference between human and computerized creativity? The computer is not able (at least not yet) to invent a game such as chess—or even a simpler game—and, furthermore, the computer does not "feel" the game: its strategy does not include such concepts as aesthetics, a sense of elegance, inspiration, or "hitting on an idea." What the human brain is able to "jump-over" to reach the best solution, the computer must