PROGRAM DESIGN WITH PSEUDOCODE

Second Edition

T. E. BAILEY

KRIS LUNDGAARD

PROGRAM DESIGN WITH PSEUDOCODE

Second Edition

T. E. BAILEY
University of Central Arkansas

KRIS LUNDGAARD

BROOKS/COLE PUBLISHING COMPANY
MONTEREY, CALIFORNIA

Brooks/Cole Publishing Company
A Division of Wadsworth, Inc.

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Bailey, T. E., [date]
Program design with pseudocode.

Includes index.
1. Electronic digital computers—Programming.
I. Lundgaard, Kris, [date]. II. Title.
QA76.6.B327 1985 005.1'2 85-15170

ISBN 0-534-05574-5

Sponsoring Editor: *Neil Oatley*
Production Editor: *Michael G. Oates*
Manuscript Editor: *John Joyner*
Permissions Editor: *Mary Kay Hancharick*
Interior Design: *Vernon T. Boes*
Cover Design and Illustration: *Arnold David Clapman*
Art Coordinators: *Michele Judge, Suzi Shepherd*
Interior Illustration: *Brenda Booth*
Typesetting: *Omegatype Typography, Inc., Champaign, Illinois*
Printing and Binding: *Malloy Lithographing, Inc., Ann Arbor, Michigan*

PREFACE

When faced with a problem to be solved with a computer, many beginning students seem to have difficulty knowing where and how to start. The first objective of this book is to present a method of problem solving that helps programmers determine the operations necessary for transforming the given information into the required information. The method uses Input/Process/Output (IPO) diagrams, which are displayed extensively throughout the book.

The second objective of this book is to present effective methods of program design and modular construction with IPO diagrams, pseudocode, and structure charts, using sequence, selection, and repetition units. This will aid students in learning from the outset good program design and structure.

The third objective is to present fundamental algorithms and concepts used in computer solutions.

We have used flowcharts in some early chapters as a pedagogical tool to help the reader visualize solutions. However, we have not used flowcharts as a tool for problem solving and program design. IPO diagrams and pseudocode are simpler to use and are more likely to result in well-designed programs.

Chapters 1–6 introduce the fundamental concepts of programming. They build on one another and should be taken in sequence. Chapters 7–10 introduce additional programming tools and can be taken when they are needed.

Although the problem-solving and program-design techniques presented in this book are certainly not the only ones available, they are particularly effective for beginning programmers.

We intend this book to be used as a complementary textbook for any beginning programming course, regardless of the computer language used. A language manual or textbook must be used for presenting a specific language in which pseudocode programs will be implemented.

We wish to thank Mike Folk and Barbara Pass for advice during the development of this material and for testing it in the classroom.

We would also like to thank the following reviewers for their insightful comments and contributions to the manuscript: Jessie M. Bethly, Southern University, and Nancy Houston, Grove City College. In addition, we thank John Joyner for correcting the infelicities of our writing and Michael Oates for providing invaluable assistance during the production process.

T. E. Bailey
Kris Lundgaard

CONTENTS

INTRODUCTION TO PROBLEM SOLVING

1

To be, or not to be: that is the question.

WILLIAM SHAKESPEARE
Hamlet

The man was a mathematical boor. . . . He was a mind-slaver and his enslaving process could be understood with extreme simplicity: he transferred technical knowledge without a transfer of values.

FRANK HERBERT
Children of Dune

Problem solving is perhaps the greatest difficulty that most students face in computer programming. For our purposes, we shall define problem solving as a procedure, specifically the procedure of determining the solution to a problem and stating that solution in a particular programming language.

There are numerous approaches to the correct solution to a problem. However, the number of clear, efficient, and easily defined approaches may be limited, and we shall limit our discussion of problem solving to a single approach. Our approach is a general method that is especially useful for computer applications.

Our approach requires a careful analysis of the problem in order to determine what information is initially given, what is to be produced upon completion, and the necessary changes or transformations needed to go from start to finish. These three steps (determining what is given, what is required, and the transformations needed) will form the foundation of our introduction to problem solving.

ANATOMY OF A PROBLEM

Several classes of problems exist. We shall be concerned, however, with problems that have solutions that can be implemented using a computer. Furthermore, these problems must be well stated—that is, clearly and sufficiently specified so that a solution can be derived; or, in simpler terms, there must be enough information given so that a solution can be obtained. We shall assume that the problems being considered have these characteristics.

A well-stated problem describes some current or initial state of affairs that is to be transformed into some other state of affairs—the required results. A problem can be divided into three parts: (1) information describing the given (initial)

situation, (2) information describing the required (final) situation, and (3) information concerning the necessary transformations for going from the initial situation to the final situation.

Think of the transformations as the set of ordered steps needed to *change* what is given into what is required. For example, if what is given is lumber, nails, shingles, and so on, and what is required is a house, the transformation rules will describe the process of changing the raw materials into a house.

Analyzing the problem for parts 1 and 2 is usually straightforward. (However, some things that are obvious, or that could be reasonably assumed, may not be specifically stated.) On the other hand, analyzing the problem for part 3 may not be straightforward. Usually, not all of the transformations will be specified; perhaps none will be. Transformations may be merely implied within the context of the problem, or they may be left entirely to the inventiveness and ingenuity of the problem solver.

A quick rule of thumb may help to identify the three parts of a problem. The given and required information, which is normally descriptive, is often stated in nouns and adjectives; transformations, which are typically actions, are stated in verbs and adverbs. This concept is summarized in the following question: What must be done to change (action, verb) what is given (situation, noun) into what is required (situation, noun)?

Example 1 Statement of problem: I am at the corner of Tenth Street and C Avenue, and I must go to the store at Fifteenth Street and L Avenue.

Part 1 Initial situation: "Tenth and C" implies a place or location (noun). This location is described very specifically: Tenth Street and C Avenue.

Part 2 Final situation: "Fifteenth and L" also implies a location, which is described as Fifteenth Street and L Avenue.

Part 3 Transformations: The action stated in the problem is *go*. The idea is to change location, and this is accomplished by going, moving, or transporting my body. (Notice that how this action is accomplished is not specified. The *how* involves tools and operations, which will be discussed in the next section.)

The analysis of the problem has produced the following result, which can be summarized in a simple diagram.

Given	*Transformations*	*Required*
Location at Tenth and C.	Change locations (go).	Location at Fifteenth and L.

This simple example clearly illustrates the initial steps of problem solving: breaking down the problem into its three fundamental parts. This process must be done accurately and completely, using only what is specified in the statement of the problem, before attempting any further analysis. An important feature of the analysis performed so far is that it represents a generalized overview of the problem and lacks details. This is exactly what is required from the preliminary analysis. By analogy to human anatomy, the preliminary analysis takes notice only of the head, trunk, arms, and legs.

TOOLS AND OPERATIONS

After a problem has been dissected into its three parts, its general anatomy becomes apparent. Next, we must perform a further dissection of the general parts in order to reveal the detailed anatomy—hands, feet, fingers, toes, knees, elbows, and so on—and the order in which they are connected. The major concern in this step is the dissection of the transformations into detailed, precise steps. Although we ignored the *how* of transformations in the last section, we shall now scrutinize part 3 of the analysis and examine tools and their uses (operations).

For Example 1, the following diagram summarizes the solution:

Given	*Transformations*	*Required*
Location at Tenth and C.	Change locations (go).	Location at Fifteenth and L.

As explained in the previous section, the required action is to change location; nothing, however, is stated regarding how this is to be done. Nonetheless, we might reasonably assume that someone intelligent enough to read the problem can certainly determine a way of going from Tenth and C to Fifteenth and L. Therefore, the process of going is left as an open choice. One's reasoning might proceed as follows: In order to go, I must have some means of movement. A basic operation in the human experience is go, and I know how to do this by selection of appropriate tools. Suppose that I have the following tools available: feet, bicycle, and car. I know how to operate each. Which tool shall I choose? That will depend on several considerations, such as: Is it raining? Do I have limited time? Will I be carrying a large load? In any event, it is left to my own ingenuity to choose the appropriate tool (feet, bicycle, or car) and use it (walk, ride, or drive) correctly to transport my body from the given location to the required location.

Since an intelligent choice of a tool and its operation is obvious in this case, there is no need to expand the middle column of the diagram. "Change locations" and "go" describe implicitly and as simply as possible the required transformation.

Still, the process of going from Tenth and C to Fifteenth and L is not completely described by the selection of a tool. Even though one may choose to walk, he or she could still raise questions about how to go to the right place—for example, when and which ways to turn and how far to go. The development of step 3 (analyzing the necessary transformations for going from the initial situation to the final situation) is still incomplete.

ORDERED STEPS FOR PERFORMING TRANSFORMATIONS

Certain additional details and ordered steps must be followed in order to ensure a correct arrival at Fifteenth and L. Even though we have allowed the *go* to include implicitly a tool and its operation, we have neglected another very important aspect of going, since *go* also implies direction. In which direction must the feet, bicycle, or car be pointed? Thus, there is a systematic and ordered sequence of activities involved in the going. This sequence, which is called the *process*, consists of a set of detailed directions or instructions. Determining the process is the

final stage in step 3 of problem analysis, and it is probably the most difficult aspect of problem solving. The process must be synthesized by answering the question "Precisely how can I make use of the tool(s), which, of course, I know how to operate, to transform the initial situation into the final situation?" For example, one might have wood (given); a saw, hammer, screwdriver, screws, nails, and glue (tools); and the knowledge to use them (operations). Nevertheless, he or she cannot produce a wooden table (required) without a set of directions for building a table (ordered steps, process). This same idea can be expressed in terms of the problem stated in Example 1. One is at Tenth and C (given) and has a car (tool) and the skill to drive it (operation), but he or she cannot go to Fifteenth and L (required) without a set of instructions detailing which direction and how far to go, where to turn, and so on (process).

How can these details be inferred from the statement of the problem? Since they are not stated explicitly, they must be inferred on the basis of common sense, certain well-known tools and operations, and perhaps some assumptions. In this case, we can infer that the streets identified by numbers go east-west or north-south. It really doesn't matter in solving this problem which points of the compass are used, so let us assume east-west. In the same manner, we can assume that the streets identified by letters are also ordered and that, if numbered streets run east-west, lettered streets run north-south. In other words, the streets of the city are laid out on a rectangular grid, and they are ordered by number and letter. Once this is recognized, the process of going becomes straightforward. One can, for example, go on C to Fifteenth, turn onto Fifteenth, and go to L, as shown for path A in Figure 1-1. But is this the only way to go?

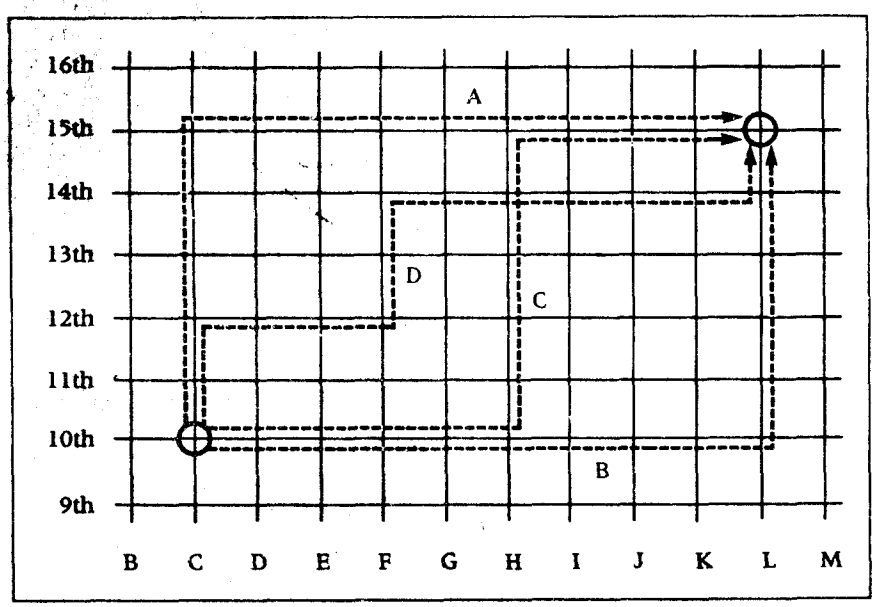


Figure 1-1. Some pathways from Tenth and C to Fifteenth and L.

Given	*Transformations*	*Required*
Location at Tenth and C.	1. Go on Tenth to L. 2. Turn onto L. 3. Go to Fifteenth.	Location at Fifteenth and L.

Figure 1-2. Going from Tenth and C to Fifteenth and L by path B (Figure 1-1).

Of course not! One could just as well go on Tenth to L and go to Fifteenth (path B). There are, in fact, many alternative paths, some of which are shown in Figure 1-1. All are equally correct, but two of them (paths A and B) are simpler than the rest. Arbitrarily choosing path B, let us expand the diagram that describes the solution into the one shown in Figure 1-2.

When inferring the information summarized in Figure 1-1, we made some important assumptions that have not yet been mentioned. All streets are through streets. Each pathway is equally pleasant. We have not considered such things as the number of stop signs and traffic lights, traffic density, smoothness of the streets, or width of the roadways. Furthermore, it was assumed that the direction to go toward Fifteenth or L was known. (Can you think of other assumptions? What if there are one-way streets?)

A process for going from Tenth and C to Fifteenth and L has now been developed, but it still needs additional refinement. What happens if one goes the wrong direction at a turn? What happens if one does not know which direction to go to Fifteenth or L? A better statement of the process takes these eventualities into account. For example, step 1 of the process, go on Tenth to L, could be expanded as follows to include the possibility of going the wrong direction: Go on Tenth to the next street. If the next street is B, turn around; then go on Tenth to L. (Can we assume that "turn around" is a basic operation that everyone knows how to do?) The process should also include a statement of when to stop the process—that is, when the transformations are completed. These changes are shown in Figure 1-3.

Since there are many processes that will work in the solution to this problem, the one shown is an arbitrary choice. Figure 1-4 shows an equally correct variation.

Given	*Transformations*	*Required*
Location at Tenth and C.	1. Go on Tenth to next street. 2. If next street is B, then turn around. 3. Go on Tenth to L. 4. Turn left onto L. 5. Go to next street. 6. If next street is Ninth, then turn around. 7. Go on L to Fifteenth. 8. Stop.	Location at Fifteenth and L.

Figure 1-3. Going from Tenth and C to Fifteenth and L, general solution.

Given	*Transformations*	*Required*
Location at Tenth and C.	1. Go on Tenth to next street. 2. If next street is D, then go on Tenth to L; otherwise, turn around and go on Tenth to L. 3. Turn right onto L. 4. Go to next street. 5. If next street is Eleventh, then go on L to Fifteenth; otherwise, turn around and go on L to Fifteenth. 6. Stop.	Location at Fifteenth and L.

Figure 1-4. Going from Tenth and C to Fifteenth and L, alternate general solution.

Based on our assumptions, the process is now complete. In fact, the solution has been clearly and unambiguously stated so that anyone can perform the transformation from Tenth and C to Fifteenth and L. It can be tested for correctness by working it by hand, using Figure 1-1.

The analysis of any problem is an iterative, or repetitive, procedure. In the development of step 3, for example, three "passes" were required. At the completion of a pass, each step of the process must be analyzed further in order to determine whether it adequately considers all reasonably possible events that might occur as the process is performed. (In our example, this included the possibility of turning the wrong way at an intersection and starting in the wrong direction.) Iteration may also be required in the development of steps 1 and 2, since more detail may be necessary in them as step 3 is developed.

FLOWCHARTS

A *flowchart* is a useful tool for visualizing a set of transformations. Flowcharts consist of certain symbols connected by arrows. Figure 1-5 shows three commonly used symbols and their meanings.

The arrows connecting flowchart symbols have two meanings:

1. They show the order in which the transformations are to be performed.
2. They show the pathway, or "flow," of given information going into a symbol and required information coming out.

Figure 1-6 shows arrows attached to the symbols to indicate the flow of information.

The *start* symbol can have only one arrow coming out since it is the beginning of the flowchart. Similarly, the *stop* symbol can have only one arrow going in since it is the end of the flowchart. The *transformation rule* symbol has one arrow going in and one arrow coming out. The *question* symbol has only one arrow going in, but it must have two (or more, in some cases) coming out—one for each possible answer to the question (usually yes or no).

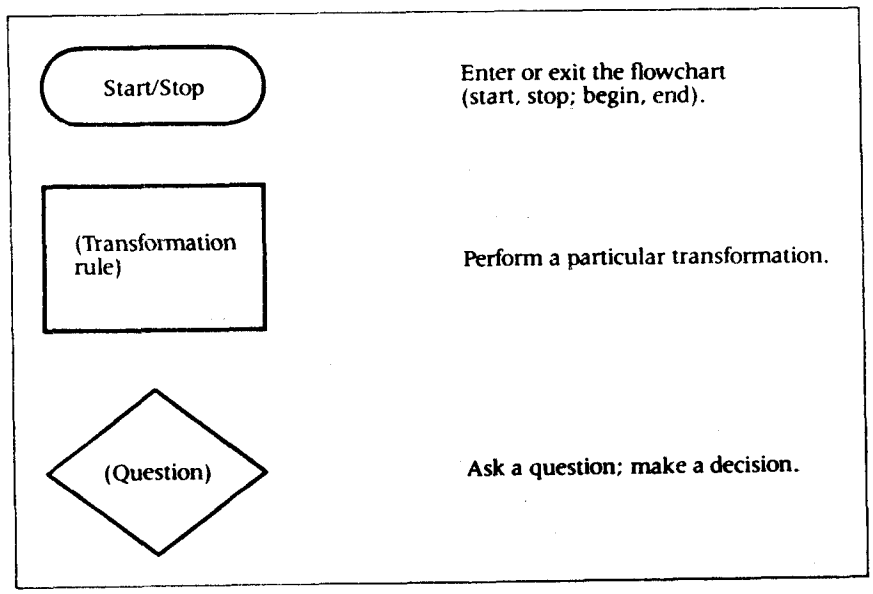


Figure 1-5. Some common flowchart symbols.

Figure 1-7 contains a flowchart for the set of transformations in the diagram in Figure 1-3. Each transformation symbol has a transformation rule written within the symbol. Each question symbol has a question written inside it; the possible answers to the question (yes or no) are written on the corresponding outgoing arrows.

The advantage of the flowchart is that it provides a visual aid that emphasizes the ordered flow of information through a set of transformations. Disadvantages are that the flowchart is a bit cumbersome and takes up considerably more space

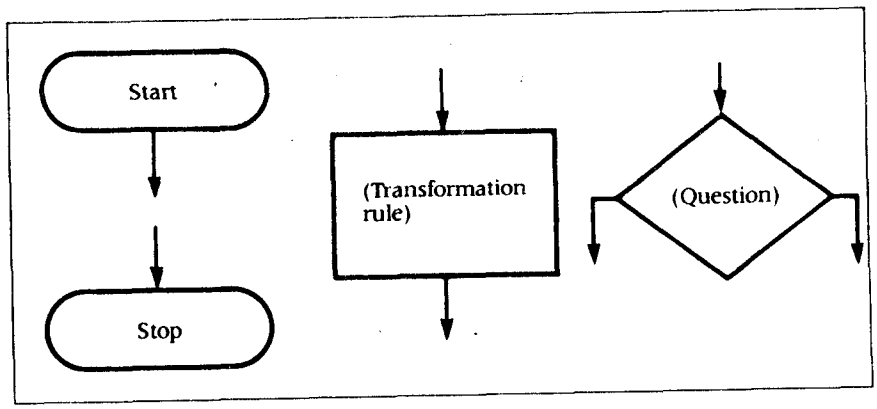
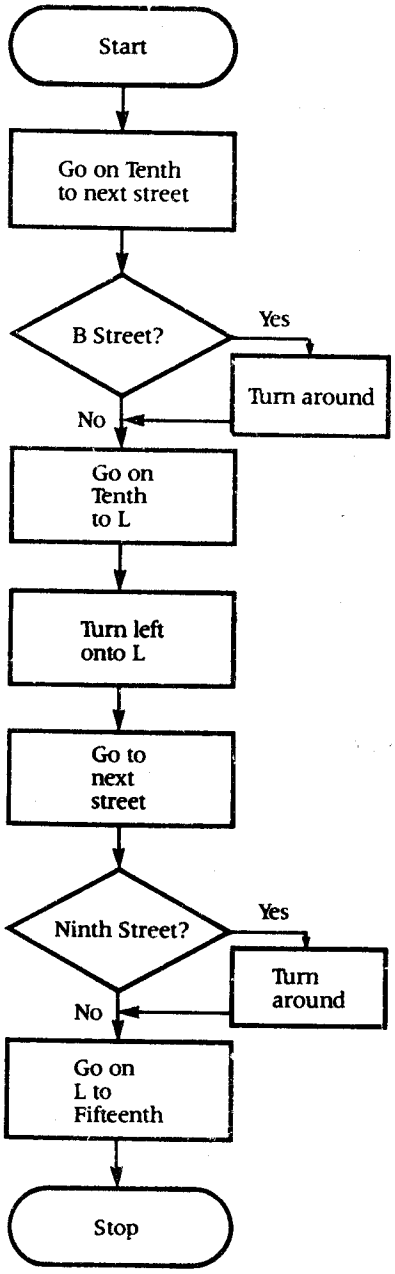


Figure 1-6. The "flow" or pathways into and out of flowchart symbols.



1. Go on Tenth to next street.
2. If next street is B, then turn around.
3. Go on Tenth to L.
4. Turn left onto L.
5. Go to next street.
6. If next street is Ninth, then turn around.
7. Go on L to Fifteenth.
8. Stop.

Figure 1-7. Flowchart for the transformations in Figure 1-3. The transformations from Figure 1-3 are stated to the right of their respective flowchart symbols.