PROGRAMMING WITH GRAPHICS

RRY MARSHALL

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Garry Marshall

Editorial Adviser: Henry Budgett

GRANADA
London Toronto Sydney New York

Granada Publishing Limited – Technical Books Division
Frogmore, St Albans, Herts AL2 2NF
and
36 Golden Square, London W1R 4AH
515 Madison Avenue, New York, NY 10022, USA
117 York Street, Sydney, NSW 2000, Australia
100 Skyway Avenue, Rexdale, Ontario, Canada M9W 3A6
61 Beach Road, Auckland, New Zealand

British Library Cataloguing in Publication Data

Marshall, G.
Programming with graphics.
1. Computer graphics 2. Microcomputers
I. Title
001.64'43 T385

ISBN 0-246-12021-5

First published in Great Britain 1983 by Granada Publishing Ltd
Reprinted 1983

Printed in Great Britain by Mackays of Chatham

Preface

This book is an introduction to the programming of graphics on microcomputers. To ensure an introductory treatment, I have stopped each of the main chapters at a point where some mathematical knowledge beyond that picked up by most people at school begins to become necessary. Some mathematical knowledge and sophistication become necessary, particularly in the field of geometry, to program *advanced* graphic effects, but I hope that one of the things this book shows is that a good deal of graphics programming can be done using a minimum of mathematics.

I have tried deliberately to keep all the graphics programs in this book as short as is consistent with showing how a particular aspect of graphics is programmed. It seemed to me important that the programs should show clearly how graphics effects are achieved. Consequently the programs are uncluttered by the programming needed for such things as making data entry foolproof and ensuring that the program can never do anything that is 'unsafe'. I am confident that the reader can deal with these aspects of the programming.

For my money the graphics capability of a microcomputer is usually its most attractive feature. Most of the early programs for microcomputers were written by programmers who had not grasped that good graphics facilities were available to them. This situation has improved considerably, but there is still some way to go before the full potential of microcomputer graphics is capitalised on by most programs. The graphics effects produced by mainframe computers for purposes such as the displays in Flight Simulators are somewhat in advance of what can be achieved with microcomputers, not only because of the superiority of the hardware but also because of superior software support and programming expertise. This should be seen as a challenge to the users of personal computers rather than anything else, providing a stimulus for the development of better graphics applications programs and graphics support programs.

The problem of how much mathematics is needed in order to program graphics effects can be a worrying one for some people. If it is accepted that very little is necessary to get started, the desire to progress to the creation of more advanced effects should be sufficient to motivate the mastery of the necessary theory. In producing three-dimensional effects, it is the visualisation of the three-dimensional situation that is as difficult as anything for most of us. This is typical of many other applications in my experience, in that it is not necessarily the mathematics that presents the major obstacle.

I have contributed a graphics column to the magazine *Computer and Video Games* since its inception, and a few sections in this book are based more or less loosely on ideas first explored there. The Appendix is based on an article published in a copy of the magazine *Personal Software* devoted to graphics. The system used to classify the graphics capabilities of microcomputers was originally devised by that magazine's editor, Henry Budgett, although I have modified it very slightly. I gratefully acknowledge his contribution, and thank him for permission to use the material.

I have been very fortunate in that many different types of microcomputer are available at my place of work. The Polytechnic of North London has microcomputers not only in its departments, but also in its Community Computer Centre to which I have had ready access. The Hewlett-Packard graph plotter on which many of the illustrations in this book were plotted belongs to the Polytechnic's Computing Service. I am grateful to all the people in the Computing Service and in the Community Computing Centre at The Polytechnic of North London for their friendly help and cooperation.

Finally, I should like to thank my wife Anne who, at a difficult time for her, has been her usual helpful self at all stages of producing this book.

Contents

Chapter One

Introduction to Graphics Programming

The graphic arts are drawing, painting and engraving. The word 'graphics' when used outside the computer field refers to such things as drawings and engravings. These can be engineering drawings or an engraving made for a poster design but, by implication, graphics are always carefully designed for the purpose of pictorial communication. Computer graphics is essentially the creation and display of pictures using a computer.

The graphics capabilities of microcomputers are among their most immediately appealing features. Whether a particular micro can generate colour displays, whether it can display realistic and accurate representations of objects, and whether convincing animated effects can be produced are all likely to interest the potential purchaser and the user of a micro. If a micro can give these effects, and others, then they can be used in the programs that are run on it, or the user can generate them himself for his own purposes.

The user's interest may be in games, business applications or educational usage but, whatever his field of interest, graphics can be an invaluable aid. Lively and interesting images will enhance the entertainment value and the lasting attraction of any game, as is well illustrated by the arcade game *Space Invaders*. Business information can be much more readily understood if it is presented pictorially, rather than numerically, by using charts, histograms and other suitable means. Educational programs are much more likely to hold the user's attention, and therefore fulfil their educational aims, if they employ attractive and interesting graphics. In fact, the use of graphics is one way in which a microcomputer can come into its own as a useful and distinctive item, occupying its own individual niche. After all, books are a good medium for education and for information transfer, but if a computer is to be used for the same purposes it needs to show

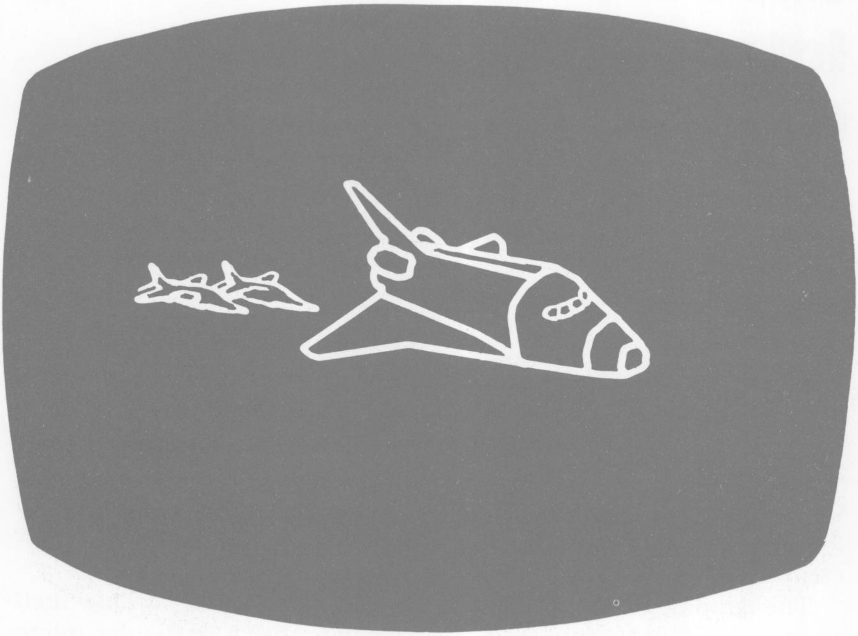


Fig. 1.1. Display produced by line graphics system.

some advantages over a book. By using imaginative graphics effects to maintain interest and to motivate further usage, a micro can show a very real advantage.

Computer graphics itself is by no means new. Mainframe computers have been used for graphics since the 1950's, and subsequently minicomputers have also been used. However, with a mainframe computer an expensive special-purpose graphics device has to be attached to the already expensive mainframe computer in order to make graphics possible. The beauty of a microcomputer is that its graphics capability is inbuilt, and besides this it is available at a price that many people can afford. This has led to a ready accessibility to graphics for large numbers of micro users. By contrast, mainframe graphics is available to only a relatively small elite corps. This is not only because the expense of large computers and their consequent siting in such places as research laboratories and universities, precludes access for most people, but also because they demand a high level of expertise. The second great bonus of microcomputer graphics is that graphic effects are not difficult to achieve, so that with a small amount

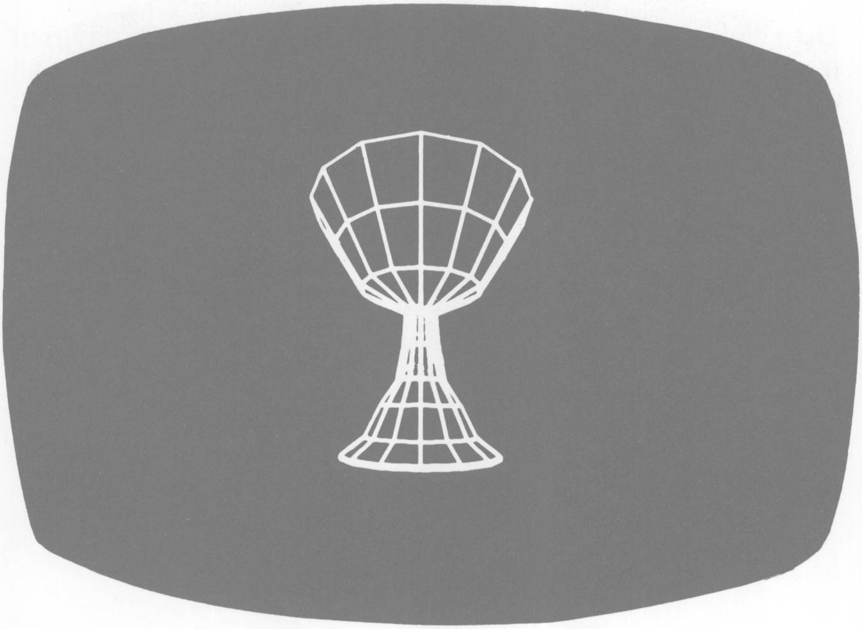


Fig. 1.2. Display produced by line graphics system.

of programming expertise the user can generate his own graphic displays at will.

Graphics are readily available on microcomputers because they make use of television technology for generating displays. This, fortunately enough, is the technology now used for producing displays in mainframe computer graphics after an evolution involving several other display techniques. Consequently, micros can draw on the expertise developed in mainframe computer graphics. Because micros cost far less, the graphic displays that they can produce cannot compete with those of the more expensive of the current mainframe computers, nor would one expect them to. However, the displays that can be generated using micros such as the BBC Microcomputer and the Atari approach what was available on mainframe computers only a short while ago. Detailed displays that are typical of what can be produced by these micros are illustrated in Figures 1.1 and 1.2.

The graphics facilities of micros

The graphics facilities possessed by micros vary considerably, but they can be classified broadly into three groups which we shall refer to as *block graphics*, *pixel graphics* and *line graphics*. All micros provide a rectangular array of dots on their screens, and their graphic displays are generated by brightening some dots and leaving others dark or, as another way of saying the same thing, by turning some dots on and others off. (This assumes a monochrome display and ignores the complexities of colour, but the principle there is fundamentally the same). The essential difference between the three types of graphics facilities lies in the size of the smallest group of dots to which the programmer has immediate access.

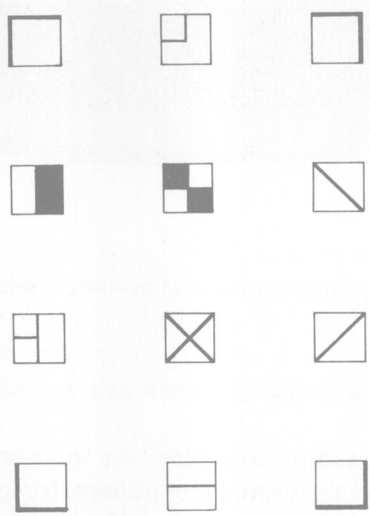


Fig. 1.3. Some common block graphics characters.

Block graphics is the term we are reserving for the graphics capability possessed by machines such as the Commodore PET. Besides being able to type letters and numbers on these machines it is also possible to type, in exactly the same way, any of a number of so-called graphics characters. Thus, with a block graphics system it is possible to type out a picture in much the same way as one would type out a paragraph of text. Clearly the capabilities of such a system are limited by the graphics

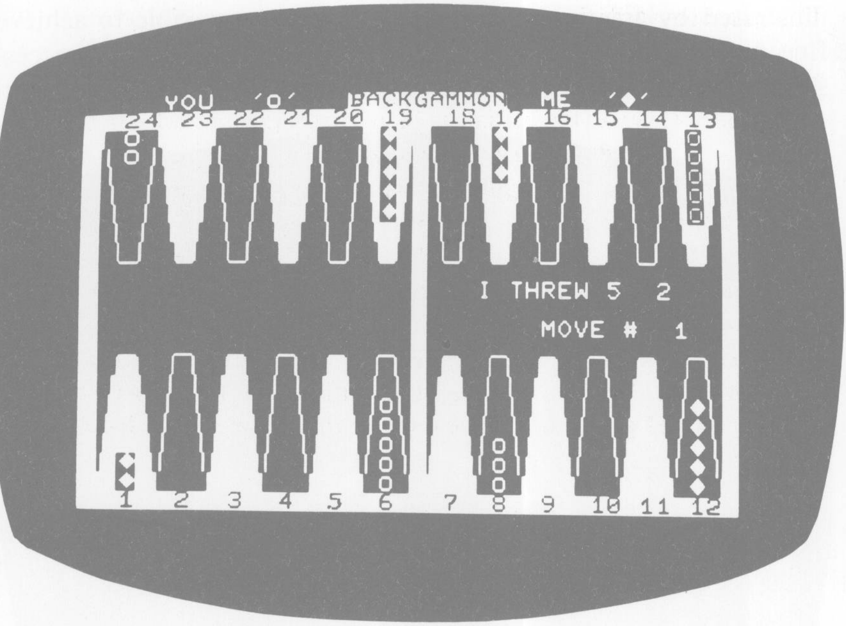


Fig. 1.4. A block graphics display.

characters that are provided. It may seem a rather primitive way to create graphics effects but, given a carefully designed set of graphics characters and some ingenuity in their manipulation, it is possible to create realistic and remarkably detailed images. Figure 1.3 shows a set of graphics characters which is a sub-set of those possessed by all the micros having block graphics capability, and Figure 1.4 illustrates a display generated with their use. As far as our classification is concerned, the essential point is that with a block graphics system the smallest group of dots which the programmer can access is the character-sized group which on the PET, for instance, is a rectangular array of 8 by 8 dots.

Micros with line graphics facilities have in a sense the most sophisticated graphics facility offerred by micros. The Apple and Atari machines are among those possessing this capability. Such micros contain in their BASICs commands such as MOVE and DRAW (although PLOT figures largely as well) with which a drawing head can be moved around the display screen and a line can be drawn from the current position to a specified position. With this capability highly sophisticated images such as the one illustrated by Figure 1.1 can be drawn. It is possible to achieve fine detail in the images because every dot on the screen is accessible to the programmer.

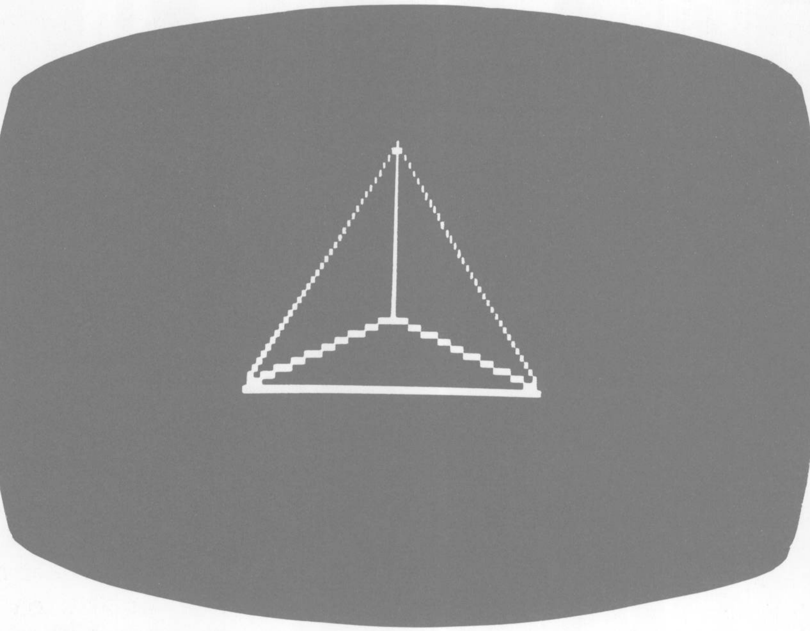


Fig. 1.5. A pixel graphics display.

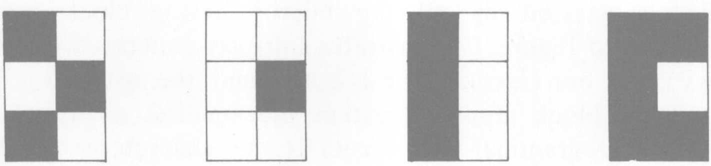
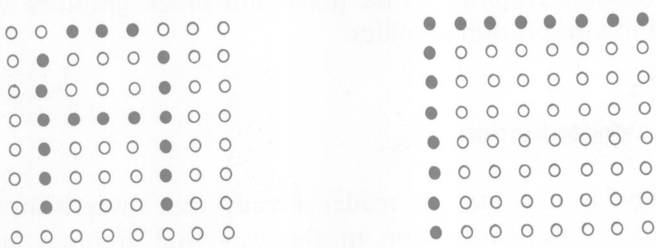


Fig. 1.6. Some pixel graphics characters.

Pixel graphics systems are in a way intermediate between the other two, and a typical display produced by a machine incorporating this system – in fact a Tandy TRS-80 – is given in Figure 1.5. A pixel graphics system is still essentially character-based, but it contains a special set of graphics characters in which the character is divided into a number of equal parts, typically into six. Some of these characters are illustrated in Figure 1.6. By using the appropriate special character, the programmer can effectively access a group of dots one-sixth the size of the group used for a character. In this way it is possible to access a smaller group of dots than it is in a block graphics system while the individual dots on the screen can still not be accessed.

Resolution

The idea of resolution can be explained in terms of the various graphics systems in use. Resolution essentially refers to the amount of detail that can be obtained in displayed images. The resolution is governed ultimately by the number of dots provided by the system for constructing the displayed images. Since all the dots are individually accessible in a line graphics system we can say that the resolution of such a system is the same as the size of the array of dots provided. Thus since the largest array of dots provided for graphics by the Apple is 192 rows each of 280 dots, we can say that its highest resolution is 280 by 192. (We write the numbers in this order because we choose to write the number of dots along a horizontal line before the number of dots on a vertical line). To give another example, the highest resolution of the Atari machines is 320 × 192 because the largest array of dots that they provide consists of 192 rows each with 320 dots.



(a) (b)

Fig. 1.7. (*a*) Pattern of dots for the letter A. (*b*) Pattern of dots for a block graphics character.

In a block graphics system, as we have seen, it is not possible to access the individual dots on the screen, but only to access a character position which is assigned a rectangular block of dots. Thus, when an ‘A’ is typed the pattern of dots shown in Figure

1.7(a) is produced while Figure 1.7(b) shows the result of typing a typical graphics character. The screen of the PET, to give an example, contains 25 rows each of which can hold 40 characters, so the resolution might be said to be 40 × 25. Since each character is assigned an 8 by 8 block of dots, the actual composition of the screen is 200 rows each with 320 dots. In this way the potential resolution of the screen is 320 × 200. It is characteristic of a block graphics system that its potential resolution is considerably greater than the actual resolution available to the programmer.

A pixel graphics system can exceed the resolution of a comparable block graphics system because of its special pixel graphics characters. To give an example again, the screen of the Tandy TRS-80 consists of 16 lines each with 64 character positions, but its special graphics characters permit each character position to be subdivided into three rows and two columns. In this way the actual resolution available is 2 × 64 by 3 × 16 or 128 × 48. Again, this is less than the potential resolution, but it is a good deal closer to it than that of the equivalent block graphics system.

The terms *high-resolution graphics* and *low-resolution graphics* are frequently used in the context of microcomputer graphics. A system capable of consistently generating highly detailed images can be said to be capable of high-resolution graphics. Although it is a matter of judgement, a resolution of at least 256 × 192 can be suggested as necessary for generating high-resolution graphics. On this basis most line graphics systems are capable of producing high-resolution graphics while pixel and block graphics systems generate low-resolution graphics.

Lack of standardisation

It is probably clear to the reader already that there is an almost total lack of standardisation in the way that graphics facilities are provided by micros. Should anyone doubt this, they need only consult the information presented in Appendix 1 about the graphics capabilities of various micros. Even the simple classification of the previous section is defied by some systems which can possess, for example, both line and block graphics. But all the micros that do conform to a particular classification will show wide variations. Items that can differ include the following:

(a) the number of dots per row,

(b) the number of dots per column,
(c) the number of character positions per row,
(d) the number of rows of characters,
(e) the order in which the rows are numbered (from top to bottom or bottom to top),
(f) the size of the block of dots assigned to a character, and
(g) the way in which a character position is divided into pixels.

Because of this variety, it is not at all easy to give a general treatment of microcomputer graphics. The classification of systems into line, pixel or block is designed to simplify the task somewhat. However, there are some underlying principles which govern the generation of graphic displays, and this book aims to present them in such a way as not only to make them clear but also to show how they can be implemented and used on any type of microcomputer.

Summary

All microcomputers use a television screen as their display screen, employing either that of a television set or one of their own. For creating images the microcomputer provides a rectangular array of dots on the display screen, and a particular image is created by brightening some of these dots and leaving others dark. The graphics facilities of microcomputers can be classified by the way in which the user is given access to the dots. If the system only permits access to the block of dots used to display a character it is called a *block graphics* system. When sub-divisions of the block assigned to a character can be accessed individually the system is referred to as a *pixel graphics* system. Finally, a system which permits independent access to each dot is known as a *line graphics* system. The degree of graininess evident in the displayed images tends to decrease from block graphics to pixel graphics to line graphics.

Some microcomputers defy this classification scheme and, indeed, there is an almost total lack of standardisation in the way that graphics facilities are provided by microcomputers. However, the classification scheme is a great help in trying to understand how the principles of computer graphics apply to microcomputers.

Chapter Two

The Production of Graphic Displays

Microcomputers produce their displays using television technology. They are either connected to a television set which produces the display or they have their own built-in television screen. For this reason a microcomputer has to be able to generate television signals to drive its display. A television picture is composed of lines, and a television signal contains special pulses to mark the part of the signal that corresponds to a line. It also has marker pulses to identify the group of lines that makes up a picture. Figure 2.1(a) shows how a tv picture is composed of lines, Figure 2.1(b) shows the part of a tv signal corresponding to one line, and Figure 2.1(c) shows the part of a signal corresponding to a picture.

As we have seen, a microcomputer display is composed of dots in the way illustrated in Figure 2.2(a). The dots along a particular line of the picture are produced by placing pulses as is appropriate in the part of the tv signal that corresponds to that line of the picture. The presence of a pulse in the signal will cause a dot to be turned on while the absence of a pulse will cause it to be off. Figure 2.2(b) shows a part of a tv signal produced by a micro to give a line of dots on the screen.

Now, when a television set is showing a programme, the tv signal is continuously transmitted to it so that the set needs no memory because the picture is being continuously refreshed. When a micro is producing its tv signal it must also produce the signal continuously, and for this reason it must be able to store the image that is to be displayed in some way. A portion of the memory of a micro is set aside for this purpose. Since the display is going to be changed fairly often, the read-write memory or random access memory (RAM) of the micro must be used to hold the image for display on the screen, and consequently the area of memory used for this purpose is known as the *screen RAM* or *video RAM*.