Advanced Graphics with the Acorn Electron

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Ian O. Angell and Brian J. Jones

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Preface

With the rapid advance of computer technology has come a substantial reduction in the price of computer hardware. In the coming years the price of peripheral devices will also tumble. This means that users with a limited budget, who previously had access only to the most elementary computing devices, will soon be able to afford the most sophisticated computers. They will also be able to escape from the limitation of tabular numerical output and buy microprocessor attachments for television monitors or inexpensive special-purpose colour graphics devices. Software, however, does not appear to be getting cheaper.

Because of the enormous capital expenditure that was required to set up graphical output in the past, both for machines and for software, the subject of computer graphics has so far been the preserve of large research groups. This inaccessibility has led to a mystique growing up around the subject and it has thus achieved a false reputation for difficulty. This book is an attempt to lay the ghost of complexity; it will also show that complicated (and hence expensive) software packages, which are naturally of great value in research organisations, need not frighten away the average computer user. For most purposes these packages are unnecessary. This book, as well as being an introduction to computer graphics, may be considered a (very inexpensive) software package: it is a lot cheaper than commercially available packages! Naturally, because of this fundamental approach, users have to achieve a reasonable understanding of their graphics device before pictures, other than those provided, can be drawn. This need not be a disadvantage; the amount of groundwork required will be seen to be very limited and, as a direct result, the user's knowledge grows along with the package and he is far less likely to misinterpret any of the graphical procedures. References are given and relevant further reading material is also recommended in order to expand the reader's horizons in the subject.

It is assumed that the reader has an elementary knowledge of Cartesian coordinate geometry (the authors recommend books detailed in Cohn, 1961, Coxeter, 1974 and McCrae, 1953 — see the references) and also the BASIC programming language (see the Electron User Guide). Many interesting programming exercises are proposed, and these should raise the standard of the reader's BASIC expertise. BASIC is a universally popular language that is available (in various guises) on all types of microcomputer, so the programs can be easily adjusted to run on micros other than the Electron: it is also a good medium for transmitting the algorithms that are used in computer graphics, so enabling

readers to translate these ideas readily into any other computer language of their choice.

The concepts necessary for the study of computer graphics are organised as a combination of theory and worked examples; these are introduced as and when they are needed in the natural progression of the subject. Program listings that form part of the examples may be considered not only as algorithms that describe solutions to fundamental graphical problems, but also as a computer graphics software package in BASIC, or just as programs to draw patterns. Alongside the examples is a series of exercises that expand on these ideas. The practical problems that are implicit in programming the various concepts of computer graphics are often more a source of difficulty to the student than the concepts themselves. Therefore it is essential that readers implement many of the program listings given in the book in order to understand the algorithms, as well as attempt a large number of the exercises. As an extra learning aid, two companion audio-cassette tapes are being made available; these contain most of the larger program listings that are given in this book. If readers are frightened by the mathematics they should run the programs first before studying the theory.

This approach to the subject has been used with great success in teaching computer graphics to undergraduates and postgraduates at Royal Holloway College. Quickly producing apparently complex pictures results in the positive feedback of enthusiastic interest. The ability to construct pictures on line-drawing and colour interactive graphics VDUs makes a long-lasting impression on the student; and the step by step approach brings him very quickly to the level of very sophisticated computer graphics. That level is outside the scope of this book, but where necessary the reader will find relevant references to guide him into the more advanced topics.

This book is aimed at those who are competent BASIC programmers but who are complete beginners in graphics. It contains the elementary ideas and basic information about pixel and two-dimensional graphics which must be mastered before attempting the more involved ideas of character and three-dimensional graphics. This is followed by a section relating to character graphics and the display of data (in line drawings and colour) – probably the most important non-specialised, commercial use of computer graphics. Later chapters introduce the reader to the geometry of three-dimensional space, and to a variety of projections of this space on to the two-dimensional space of graphics devices. The related problems of hidden lines and hidden surfaces, as well as the construction of complex three-dimensional objects, are dealt with in detail. Finally we return to advanced ideas in BASIC programming and give a large worked example of a video game (to be found on cassette 2).

Graphics is one of the most rapidly expanding areas of computer science. It is being used more and more in the fields of Computer Aided Design (C.A.D.), Computer Assisted Management (C.A.M.) and Computer Assisted Learning (C.A.L.). At one time it was only the big corporations such as aircraft and auto-

mobile manufacturers who used these techniques, but now most companies are realising the potential and financial savings of these ideas. What is more, not only is computer graphics profitable, it is fun! The Acorn Electron microcomputer is an ideal machine on which to learn the basics of computer graphics, and an excellent springboard up to the most sophisticated (and expensive) graphics devices.

We hope this book will display some of the excitement and enthusiasm for computer graphics experienced by us, our colleagues and students. To demonstrate just how useful computer drawings are for illustrating books and pamphlets, all the pictures in the following chapters were drawn by computer specifically for this book.

1984

Ian O. Angell
Brian J. Jones

Introduction

This book may be read at a number of different levels. Firstly, it can be considered as a recipe book of graphics programs for those who simply want to draw complex pictures with their Acorn Electron. We naturally hope that the reader, having drawn these figures, will be inspired to delve more deeply into the book in order to understand how and why the programs were constructed. Secondly, some of the programs can be used as a package to produce and to label data diagrams (pie-charts, histograms and graphs) for business and laboratory applications. Finally, and the main objective in writing the book, it is an introductory text to computer graphics that leads the reader from the elementary notions of the subject to such advanced topics as character graphics, construction of three-dimensional objects and hidden surface (and line) algorithms.

The complex programs given later in the book are much too involved to be compiled as single listings; furthermore, there is a great deal of repetition in the use of elementary algorithms. Therefore the *top down* or *modular* approach is used in writing and in explaining programs. The solution to each major graphics problem is conceived as a series of solutions to subproblems. These subproblems can be further broken down into a set of problems to be solved (*modules*). Such modules are programmed in the form of BASIC procedures. Each is given an identifier (in lower case characters) and will solve a particular subtask. Sub-modules are then combined to solve the major graphics problem. The program listings present the algorithms that are needed for the solution of subtasks, and the naming of the procedures makes an understanding of the algorithms easier. We use lower case characters for procedure identifiers (and groupings of procedures in the text) only: all other program variables are in upper case characters to avoid confusion.

Two cassette tapes are available to accompany the text; they contain all the larger listings in the book, as well as the data for diagrams and character sets used in later programs (which would otherwise have to be constructed by the readers themselves – a rather time-consuming process). The first cassette consists of the two- and three-dimensional geometrical programs, and the second contains the character graphics manipulation, diagram construction and video games etc.

A list of complete programs is given at the end of each chapter, together with suitable data values, for those who want nothing more than to run these programs. In fact it is a good idea for everyone, including the more serious readers, to LOAD the relevant programs from the tape and run them before reading any particular chapter.

Our program listings contain large numbers of REMarks, as well as a liberal use of spaces to make individual statements more readable. We also separate procedures with blank lines by adding spaces to the END and ENDPROC statements. This makes the programs easy to read. We recommend listing with LISTO1 in mode 6, but it is very wasteful in terms of computer store. We have placed most of the REMarks on lines ending in a 9, whereas most executable statements (and a labelling REMark before each procedure) are placed on lines ending in a 0. You can delete most REMarks before running a program by using the simple REM-stripper (type AUTO 9, 10 and keep pressing the RETURN key).

On the other hand you can use the 'derem' program (listing I.1) which deletes all REMark lines as well as multiple spaces, and spaces before colons. You should place your (target) program usually at PAGE = &E00 and then change PAGE = &5700, and in mode 6 load 'derem' and RUN. It will ask you for the PAGE of the target program and then proceed with the required deletions and finally RUN your program.

Listing I.1

```

10 REM a program to strip out REMARK lines,
    SPACES before COLONS and multiple SPACES.
20 REM LOAD this program at PAGE=&5700
30 MODE 6
39 REM P$ is the HEX PAGE value of the program to be altered.
40 INPUT "Print PAGE value of the target program, as a HEX constant",P:
50 IF LEFT$(P$,1)<>"&" THEN P$="&"+P$
59 REM ADD goes through the memory locations of the original
    program. NADD runs through the locations after adjustment.
    ADD>=NADD.
60 ADD=EVAL(P$) : NADD=ADD
69 REM End of program found ?
70 IF ?(ADD+1)=&FF THEN GOTO 230
78 REM There is a <RETURN> (&0D) at the beginning and
    between each program line.
79 REM We are at the beginning of a program line.
    Locations ADD+1 and ADD+2 contain the line number.
    Location ADD+3 holds the length of the line.
80 PRINT "Considering Program line : ";?(ADD+1)*256+?(ADD+2)
90 STO=NADD : L=?(ADD+3)
99 REM Delete any line beginning with a remark ( code &F4 ).
100 IF ?(ADD+4)=&F4 THEN PRINT "Deleting a REMark" :
    ADD=ADD+L : GOTO 70
109 REM Copy from original to new memory locations.
110 FOR I=ADD TO ADD+3
120 ?NADD=?I : NADD=NADD+1
130 NEXT I
140 IF L<6 THEN GOTO 200
150 FOR I=ADD+4 TO ADD+L-2
159 REM Change a double SPACE to a single SPACE (&20).
160 IF ?I=&20 AND ?(I+1)=&20 THEN PRINT "Deleting a SPACE" : GOTO 190
169 REM Change a SPACE and COLON (&3A) to a COLON and SPACE.
170 IF ?I=&20 AND ?(I+1)=&3A THEN PRINT "SPACE and COLON found" :
    ?I=&3A : ?(I+1)=&20
180 ?NADD=?I : NADD=NADD+1

```

```
190 NEXT I
199 REM Correct length of new line and return for next line.
200 ?NADD=? (ADD+L-1) : NADD=NADD+1
210 ADD=ADD+L : ? (STO+3)=NADD-STO
220 GOTO 70
229 REM Place final line in the adjusted program.
230 ?NADD=?ADD : ? (NADD+1)=? (ADD+1)
239 REM Change PAGE in order to RUN the adjusted program.
240 CLS : PAGE=EVAL(P$)
250 *FX138,0,82
260 *FX138,0,85
270 *FX138,0,78
280 *FX138,0,13
290 END
```

To give you an example of the type of program you will be writing after having read this book, and to show you what to expect in the following pages, we now show you a program that draws figure I.1, a drawing of a wire body of revolution — a goblet.

Figure I.1

The program requires listings 2.1 ('start'), 2.2 (two functions FNX and FNY), 2.3 ('setorigin'), 2.4 ('moveto') and 2.5 ('lineto'). These procedures form part of a library 'lib1' of routines for drawing line figures on a television screen.

To 'lib1' must be added listings 3.3 ('angle'), 8.1 ('mult3' and 'idR3'), 8.2 ('tran3'), 8.4 ('rot3'), 9.1 ('look3') and 9.2 ('main program'): procedures that form part of a library ('lib3') and which are used for transforming and for observing objects in three-dimensional space.

Listing 9.10 ('revbod') is also needed, together with the 'scene3' procedure given in listing I.2.

Listing I.2

```

6000 REM scene3 / goblet
6010 DEF PROCscene3
6020 LOCAL I%,THETA,TD
6030 DIM X(24),Y(24),XD(12),YD(12)
6040 DIM A(4,4),B(4,4),R(4,4)
6050 DATA 0,-16, 8,-16, 8,-15, 1,-15, 1,-2, 6,-1, 8,2,
        14,14, 13,14, 7,2, 5,0, 0,0
6060 RESTORE 6050
6069 REM Generate definition set.
6070 NUMV=11 : N1=NUMV+1
6080 INPUT"NUMBER OF HORIZONTAL LINES",NUMH
6090 INPUT"INITIAL ROTATION",PHI
6100 FOR I%=1 TO N1
6110 READ XD(I%),YD(I%)
6120 NEXT I%
6130 PROCIdR3 : PROClook3
6140 PROCrevbod
6150 ENDPROC

```

Figure I.1 requires the data $HORIZ = 60$, $VERT = 45$, $EX = 1$, $EY = 2$, $EZ = 3$, $DX = DY = DZ = 0$, the number of horizontal lines $NUMH = 16$ and the initial rotation $PHI = 0$. Each value has to be typed individually, when requested by the machine. Run the program with different data values. What happens if $HORIZ = 100$, $VERT = 75$ and the other values stay the same? Set $HORIZ = 80$, $VERT = 60$, $EX = 1$, $EY = -2$, $EZ = 3$, $DX = 1$, $DY = DZ = 0$. Try $NUMH = 30$ or $PHI = 0.1$. You will have to read up to and including chapter 9 to understand the details of what is happening.

This example illustrates the reasoning behind the layout of this book. Assuming that you are a fast typist, or that you have bought the accompanying cassettes, then a relatively complex three-dimensional picture can be constructed very quickly with a minimum of effort. Even one-finger typists (like the authors) will have little difficulty in implementing this and the other programs, before they go on to study the book in detail.

We hope that this example will inspire you to implement *all* the programs in this book, to try most of the examples, and then to go on and draw your very own computer graphics pictures.

Now read the rest of our book and we wish you many happy hours with your Acorn Electron.