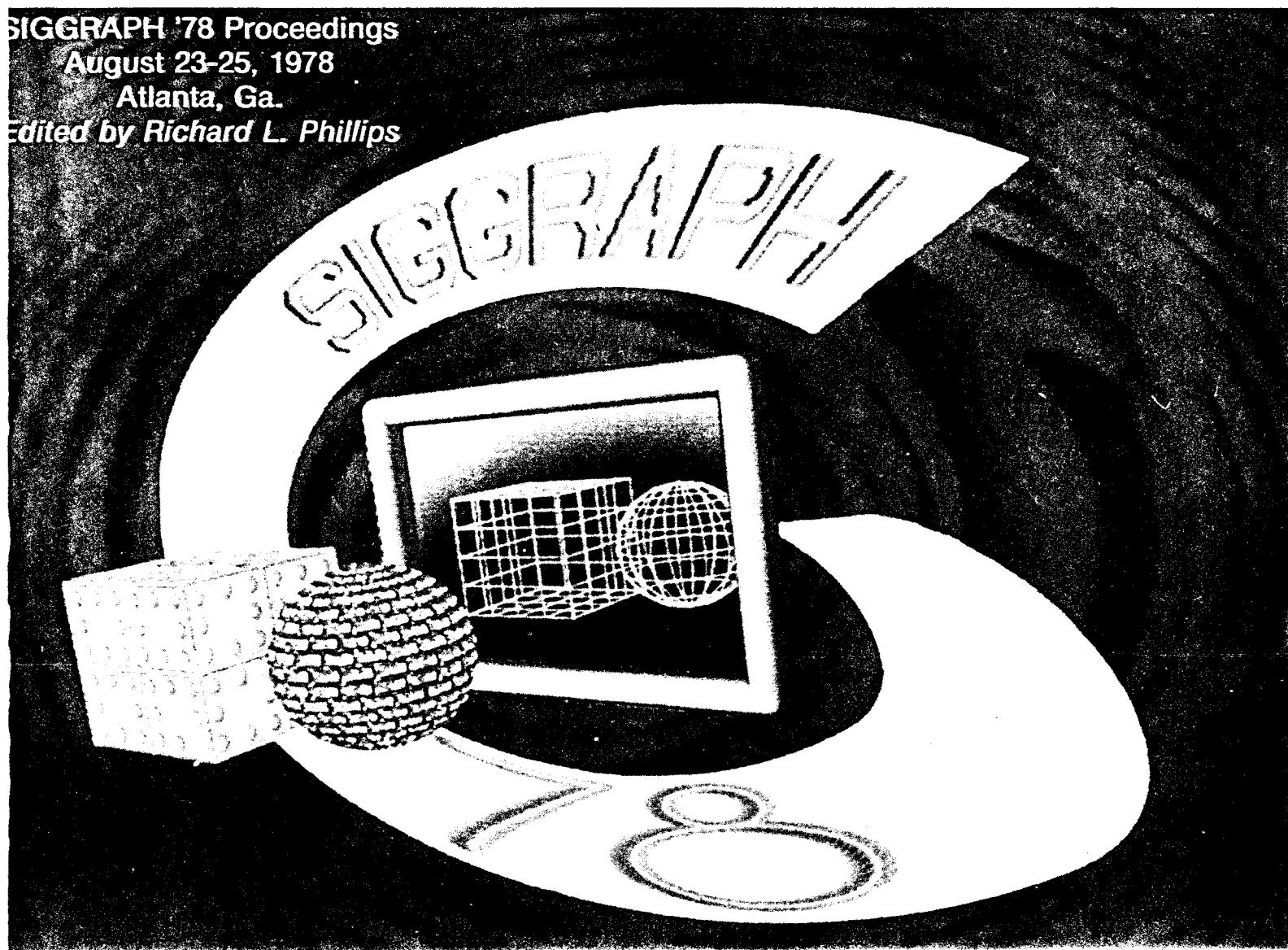


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BASIC Zgrass--A Sophisticated Graphics Language  
for the Bally Home Library Computer

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Abstract

Home computer users are just now discovering computer graphics. Modest extensions to BASIC allow plotting but not much more. The Bally Home Library Computer, however, has hardware to aid implementation of video games. Custom integrated circuits working on a 160X102 pixel (2 bits per pixel) color television screen allow certain forms of animation in real time. To give this power to the user, BASIC Zgrass has been designed and implemented. It is an extension of BASIC that allows parallel processes, picture objects that move, scale and group together as well as several drawing modes. There are also software controls of a three-voice music synthesizer, interactive input devices, a film camera and an IEEE bus interface. We will concentrate mainly on the language design for making it all easy to learn and use.

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Introduction and General Motivation

Zgrass can be called an immodest extension of BASIC (Ted Nelson refers to it as "Super BASIC" [1]). It is an extension in that graphics support and user instruction facilities have been added to the capability of running BASIC programs copied out of a hobbyist computer magazine. It is immodest in that great liberties have been taken to weed out some of BASIC's undesirable programming conventions. Zgrass is actually a video game programming language designed specifically to encourage creation of beautiful animations in short order. It is also designed to teach many of the important concepts of interactive systems and 2-D computer graphics.

The hardware used is the Bally Home Library Computer built around the Bally Arcade unit. It is a Z-80 based machine with special integrated circuits which help the processor manage the 160x102 2-bit-per-pixel color output connected to any standard color tv set. The alphanumeric generated by program output and keyboard input are video mixed over the color graphics so text is not constrained to the 160x102 format. The two bits in each pixel indicate one of four bytes from which an index into a 256-element color map is taken. Thus, four of 256 colors can be on the screen at once. The hardware also includes some tricks which have been found useful in professional video

arcade units. Its projected cost, without color tv, is about \$750.00, including the arcade unit.

Zgrass itself takes up 16k bytes of ROM storage and has 16k bytes of RAM for user storage and system use. An additional 16k ROM (referred to as the 'extension' below) plugs into the side and provides room for a compiler and other features. Audio cassette storage and modem linkage to other computers is provided. Software for driving optional intelligent floppy disk drives is also built-in. Further hardware in this unit includes four hand controls, a 24-key pocket calculator keyboard, a three-voice sound generator and an IEEE Bus interface. Zgrass is the operating system for this computer as well.

Zgrass design concepts are rather different from those apparently underlying the current batch of home computer systems. Home systems are now trying very hard to be cheap minicomputers for expert users. These users when at home can be likened to the ham radio operators of the nineteen fifties, able to change diodes, violently shake intermittent boards and, in general, understand the innards. These persons can also get gratification from fighting with manuals and the trials of the latest software release, just as we professionals do for a living.

Zgrass, however is designed for the two-hour-a-week user. This type of person is guaranteed to continually forget the syntax and semantics of whatever software exists. Zgrass is designed (certainly at the cost of computer time and memory use) so the user does not have to rely on a manual to decipher everything. In short, this system is trying to be the Model T of the home computer industry, with all that implies. We shall see.

Above all, Zgrass is designed to be as attractive and as fun as pinball but considerably more intriguing and useful.

General Zgrass Concepts

"Right away" is the foremost design concept of Zgrass. Positive experiences in the first two hours of play are essential. When it is not part of your job or intended career, you must be able to do interesting, beautiful things right away, without reading a five-pound manual.

BASIC is now the home computer language. BASIC was designed as a teaching language and shines in its simplicity and easy matrix operations. It is, however, a poor language for the

manipulation of anything but numbers. It has no features that make writing large programs (over 200 statements) easy. Its subroutine capability is archaic. But, it is obviously a success in what the designers intended, otherwise it could not presently be the universal home computer language.

In particular, though, BASIC is a poor language for animation. To be sure, plotter art and decaying sine curves are well suited to BASIC. But our almost eight years of experience with the GRASS language[2] and Dan Sandin's color video Image Processor[3] as well as being directly or indirectly involved with roughly half of the most popular arcade video games, has given us insight into the potential of a color tv set, and you just cannot do a tv set justice in BASIC.

The next several pages will give details on syntax of Zgrass, but first we will further consider the "right away" criterion. Anyone who already knows BASIC should be able to write Zgrass programs immediately. For those persons in America who do not religiously read "BYTE" or "Creative Computing" (a sizable part of the population), we have been developing self-paced instructional software for Zgrass. The prototype system now functions quite well in GRASS (see paper by Towle and DeFanti, these proceedings). Both GRASS and Zgrass have enough supervisory functions and error trapping features to allow a good programmer/educator to write programs which execute and verify instructional programs written by beginning students. We feel that the chief problem in teaching programming is that it, as an activity, is poorly simulated by the examples and the Backus-Naur-type syntax information usually found in manuals. Normal programmers have fellow workers, consultants or at least other students around to help out. The home user has no such recourse.

The essence of the teaching problem stems from the fact that novices have tremendous problems with meaningless (to them) error messages. You really have to know nearly everything about a system before you can start knowing why what you have typed does not work. This is absolutely not an overstatement of the problem.

All this commentary leads directly to computer aided instruction. While CAI has not quite lived up to its expectations for teaching other subjects, it can be used to teach people how to program. It is relatively straightforward to lead the user through commands, interactively teach looping concepts and verify the results of carefully chosen problem sets. All possible errors can be trapped and explained in detail. Our experience with this type of teaching is very supportive--non-programmers (primarily art students and a few university officials) can be doing fascinating graphics of great beauty in half an hour. The whole process has the feeling of a game and is consistently rewarding. Providing internal system support for these teaching programs is no doubt the second most important design concept of Zgrass, after "right away" of course.

Note that few (if any) programming languages allow you to write programs to interactively teach programming. Smalltalk[4] and Logo[5] teach by user experimentation in surroundings not lacking professional help. Plato[6] has no student program or storage space (only authors can write and store TUTOR programs). One could probably design

some CAI programs in Snobol or Lisp but these are hardly languages for novices and they are not known for their lucid error message handling, or availability on micros. Perhaps a graphics-extended APL might do. It would be wonderful if the experience with Zgrass encouraged others to design extensions to languages with teaching in mind.

#### Zgrass Technical Details

Zgrass is an interpreter of commands and assignment statements stored internally as ASCII strings. These strings may be entered and executed line by line, formed into programs (called "macros"), edited, and even built and pulled apart by string manipulation primitives. (A compiler which eliminates most of the interpretive overhead and which takes better advantage of the resident hardware floating point unit is part of the 16k extension ROM.)

We are determined to maintain compatibility with at least TINY BASIC (it is hard to say what "standard" BASIC really is). Since BASIC has line numbers, Zgrass labels must start with a number (e.g. 100, 10bekenobe, 707crash, etc.). A BASIC program copied out of "BYTE" would simply have a lot of extraneous labels. Labels in Zgrass are obviously not used to order and edit the statements as in BASIC since one would hardly like to have alphabetically ordered labels and Zgrass has a good on-screen editor anyway. Our definition of compatibility is restricted to executing perfect programs written in BASIC. Getting them in, editing, executing and debugging them is done differently.

Commands are made up of a keyword followed by zero or more operands. Examples of commands are:

```
goto 4jail
move deathweapon,x1,y1
clear
input dea,fbi,c
print beep,"who loves ya, baby?"
```

(some of the more idiosyncratic BASIC commands, notably "if" and "for" have their peculiar syntax retained for compatibility).

Commands are gentle to users. If not enough arguments are supplied, if an incorrect argument is given or the argument is non-existent, a special error fixup routine is entered. This routine prints out the command in error, points at the argument in error and says, for example, "NO! this command wants a variable name here." The user can then type in a correct argument and the command goes on. He can also elect to enter command mode to create a missing name, for example, and then resume the above process. All this will happen whether commands are entered line-by-line or executed as part of a macro.

Note that all commands are more or less self documenting. You can type the command name and it asks you for the operands. This error facility allows one to get by trivial syntax errors without constant re-editing. It is also a sloppy way to get input to macros, although there are several conceptually clearer (to computer folk) ways.

Many commands have options indicated by postfixing the command name with a hyphen plus a modifier (e.g. "input-string" which can be shortened to "in-str" or even "i-s"). The hyphenated option construction is more English-like than

single-character switches and it helps keep down proliferation of command names.

Since every command has an internally stored list of what argument types it wants, the "help" command can easily print these out with options (there are about 20 different argument types in Zgrass, like number, string, expression, picture prototype, array and so on). Further syntax and semantic information is available in the manual but the information you need most often is at your fingertips "right away."

A few more details about variables are necessary. Variable names (macros are actually string variables) can be any length and must start with an alphabetic character. Variables used as macros may not have names which conflict with system names. Global variables start with lower case letters and local variables start with upper case letters. The system decides whether a variable is a numeric or string variable by examining the context in which it is first used.

(Commands are terminated by semicolons or carriage returns. The alphanumeric generator which is video mixed over the color graphics or routed to a separate monitor puts up sixteen 32-character lines. The alphanumeric handler automatically folds lines over 32 characters long for display purposes but does not insert a carriage return. A special character indicates folded lines.)

Arithmetic statements are similar in format to assignment statements in BASIC or FORTRAN, with the exception of the left arrow used. The parser automatically changes equals signs (which are used for conditionals) to left arrows to maintain compatibility with BASIC yet allow a sophisticated expression evaluator to operate unambiguously by not having to deal with multi-purpose operators. Examples of arithmetic assignment statements are:

```
abc←sin(arg1)+cos(arg2)
babarum←1.2
c←whodunit(f,g,huh)
```

where the last example contains a user-defined function (a macro, of course).

Numeric variables are kept in fixed or floating point by the system, switching mode as necessary without user knowledge. The luxury of a floating point arithmetic unit helps calculation speed considerably. There are also reserved system variables which hold the values of the hand controls, keypad keys, external I/O strings and other special things.

Strings are assigned as follows:

```
tom→"this is a single line"
sam→tom&tom&babarum          ;.concatenat
cr→'
'                               ;.to enter a carriage return
mymacro→<print tom,cr,tom," again"
stuff←hello>                  ;. stuff gets "hello"
for a=1 to 10
print stuff,a
next a>
```

The last example shows nested assignments and a way to create a macro. Note that acceptable string delimiters are ",',<, >,[, and ], the last four of which must be balanced. String decomposition is handled by a variety of string commands in the 16k extension.

Any string can be executed in Zgrass. If it contains meaningful commands, it can be used as a program. Again, programs in Zgrass are called "macros." Macros can call other macros, call themselves, execute in foreground or in parallel with other macros in the background, supervise other macros and interact with macros running on other Zgrass machines.

Zgrass differs from BASIC greatly when it comes to subroutine linkage. Zgrass has a very convenient and conceptually clear way of passing arguments--you simply make believe the macro is a command and use standard command syntax. Furthermore, the "input" command (for numbers) and the "input-name" and "input-string" commands (for strings) fetch the arguments passed in a way that automatically request user input from the terminal if not enough arguments are passed. This linkage is discussed in more detail below.

Looping and control transfer is done with "goto," "for/next" and "gosub." (Gosub is retained for compatibility.) A version of goto called "skip" has the option of jumping relative a number of lines, a good feature for those quick loops in which you forgot to put the label. There is also a "return" command which can pass an argument back if it is a function call like "whodunit" above.

When a macro is asked to execute (by typing its name as the first thing on a line, like a command), the system builds a macro invocation block (MIB). The MIB holds information about local variables, for/next blocks, argument and data lists and so on. When the macro is done, the MIB is deleted along with all the pieces hanging off it. The storage allocation/reclamation algorithms used are again similar to GRASS's.

Numeric arguments are passed using the "input" command. It is similar to "input" in BASIC but it first checks the argument list. If there is an argument, it is grabbed. Otherwise, the user is requested to enter the value. Input works in concert with "print" which suppresses output when arguments are present. (Of course, there are options to input and print which force terminal I/O.) Thus, a macro that has lots of prompting information can be called by another macro without all sorts of editing to remove the prompts, but the macro will wake up and start asking questions if not enough arguments are supplied. One can create self-documenting macros which are efficient, yet help out when necessary. (How many times have you forgotten the arguments to a subroutine?)

The "input-name" command functions similarly for strings and is used to get names passed as arguments. You use the "@" operator to indirectly reference strings. For example:

```
getandmove→<lagain print "gimme a pixname"
inp-name gettemp                ;.get name
if gettemp='',return            ;.if null, return
get-tape @gettemp               ;.get it from tape
move @gettemp,x3,y3             ;.attach control3
display @gettemp                ;.and show it
goto lagain>
.
.
.
getandmove apple,witch,titles,,
```

where the last line is the call and the lines above are the macro definition presumably entered before the call. Comments are lines or sub-lines which start with a "."

The "input-string" command expects string delimiters around arguments passed so that whole commands can be arguments (you cannot pass a comma with the input-name option). This is important for the construction of teaching and verification programs, among other things. If the argument is not there, input-string will require input from the keyboard, but without the string delimiters, just like input-name.

The principle here is to make macros look like system-defined commands as much as possible, a rather loose definition of extensibility, but one that is meaningful when speaking about interpreters (a conclusion adapted from comments in [7]).

#### Picture and Pattern Drawing

Zgrass has several predefined variables which cause drawing on the screen when they are written into. To display a point, you set variables xs and ys to the x and y coordinate. When you set variable cs to a value from one to four, the point is displayed with the color value indicated by the value of cs. There are also the "line," "box," and "circle" commands which draw vectors, and filled rectangles and ellipses on the screen.

#### Picture Animation

Once a picture is drawn on the screen, all or part of it may be stored as a picture prototype with the "snap" command. Picture prototypes are pixel lists in this case and are kept in user 16k RAM rather than in the screen 4k RAM. So, a picture is something you see on the screen and a picture prototype (or "prototype" for short) is its representation in user memory.

One then attaches the prototype to a variable, time-based variable (a user-defined special variable whose value varies automatically over a given time period), hand control, or user-defined function. The prototype is displayed with the "display" command. After that, anytime the variable or function changes, the prototype will be erased with an "exclusive or" write and rewritten with its updated translation or other transformation with an "exclusive or" write. This technique lets pictures of one color pass over pictures of another color without leaving holes (using standard bit plane raster scan graphics techniques). There is an interrupt level routine which manages movements of prototypes and a host of other details, along the lines of a conventional refresh graphics driver. The user has a simple way to indicate what maximum percentage of time should be allocated to interrupt level updating, the rest being left for command processing.

The same interrupt routine also manages picture prototype lists made up of lists of points, vector endpoints, box and circle drawing information. With the 16k extension, rotation and scaling of these lists is possible. Prototype lists, of course, have to be built up rather than snapped using options to the line, box and circle commands. The user can access individual endpoints and manipulate the prototype as a whole. Of

course, there can be many prototypes floating around at once.

Again, the user's aesthetics and perceptions are essential. Since everything is real-time (or close to it) the user can easily see the effect of various commands on the screen, the implications of varying amounts of interrupt processing time, the ways of using different colors, and so on.

Prototype lists and patterns can be grouped into a tree structure which allows concatenation of transformations. Moreover, the "select" command specifies a sequence of pictures to be put up and erased in round-robin fashion (imagine several views of a walking "man" being switched to provide the illusion of walking). A simple Super 8 camera hookup allows more complex, synchronized sequences to be filmed, if desired.

#### Conclusions

Zgrass is designed to be a first programming language which encourages both novices and experts to learn about color graphics, generate meaningful and pretty displays, possibly make Super 8 movies, and perhaps even access governmental databases and control electric train sets. The software is designed to be multi-leveled and rich with feedback. Considerable research into the teaching aspects has been folded into the design.

Continuing developmental effort along these lines now concerns higher resolution displays, much faster microprocessors, parallel programming techniques and connection to videodisks and other television equipment. Zgrass is one way you can control the amount of sex and violence on your tv set.

#### References

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Addendum: Zgrass Command List (in addition to BASIC)

(The commands beginning with a '\*' are in the 16k extension.) (Not all options are indicated.)

command name	function		
bcx	draws a rectangle on the screen & has options for building picture prototype lists	select	causes picture prototypes to be switched round-robin fashion on the screen
*change	changes the values of an endpoint in a picture prototype list	snap	takes a screen image in rectangular bounds and makes it into a movable picture prototype
circie	draws an ellipse on the screen & has options for building picture prototype lists	sync	tells the system how much time to devote to interrupt-level updating versus command processing
clear	clears the screen	*vip	allows a macro to be executed at interrupt level (stands for "very important program")
*close	closes off an open picture prototype list		
colors	chooses 4 colors of 256 for screen use		
*compile	compiles code for speed		
copy	makes a copy of a picture prototype with a new name		
delete	deletes and reclaims storage of a named thing		
display	causes a picture prototype to be exclusive or'ed onto the screen and be updated when necessary		
*film	sets up filming mode for a Super 8 camera		
*fetch	retrieves a given endpoint in a picture prototype list		
get	gets a macro, array, picture prototype list, etc. from tape, disk, etc.		
group	collects picture prototypes into a group which can be referenced with a single name. Transformations may be done to the group as a whole or to individual members.		
help	prints commands and required argument types		
ieee	provides interface to IEEE bus		
input	used to input numbers, strings from terminal or passed argument lists		
line	draws a vector & has options for building picture prototype lists		
memory	gives a usage map of memory		
move	attaches a picture prototype to two variables, devices, etc. so that when they change, the prototype is automatically erased and redrawn in the new position with options for "exclusive or" or "load/store" read and write to screen		
*onerror	traps errors to a user's routines		
*open	allocates storage and starts up a picture prototype list		
*pattern	allows a pixel list to be directly built rather than snapped		
play	interprets a string, array or picture prototype as a musical score to be played by the three-voice synthesizer		
put	stores a macro, array, picture prototype list, etc. on tape, disk, etc.		
rename	renames a named thing to a new name		
*rotate	like move but the prototype is rotated		
*scale	like move but the prototype is scaled		