CALCULATOR: A GIS CONTROL PANEL FOR EXTENT, SCALE AND SIZE MANIPULATION

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ABSTRACT

Most GIS interfaces handle extent (dimensions on the ground), scale (e.g., feet per inch), and size (dimensions on screen or media) by solving the equation [Extent / Scale = Size] in a forward manner. While easily understood, this approach requires users to perform iterative experiments or scratchpad calculations if constraints on one or more of the variables are present. When large maps (e.g., 3 feet and longer produced on plotters) are involved, this problem contributes to the difficulty of layout on relatively small workstation screens.

Using the interface tools in Arc/Info Macro Language (AML), we developed a prototype control panel (Calculator) that allows users to manipulate the equation parameters, dependence of variables, and direction of solution. The Calculator is a *visual formalism* similar to a spreadsheet. Results are immediately visible to the user both as numerical values on Calculator and in the map layout. The Calculator was then linked to other panels that control detailed aspects of layout (e.g. spacing between legends and titles, etc.) so that the resulting sums of dimensions can be controlled.

We describe the simple algorithms and complex decision tree of the underlying code. This calculator analog appears to be a useful supplement to direct layout manipulation for experienced GIS users.

INTRODUCTION

Large maps are a popular and important product of GIS. Maps up to several feet long, in large scales such as 1000 feet per inch[1], are often requested for facilities design, use at construction sites, earth science and environmental fieldwork. Public displays, presentations, posters, etc. can require even larger dimensions. In these sizes, the time, expense, and wasted paper and inks of bad plots make a single run highly desirable. (This is especially true if the plot is done offline by a service bureau.)

Direct manipulation of graphic layout is used in most what-you-see-is-what-you-get (WYSIWYG) graphics packages. The user moves a cursor (by operating a mouse, trackball, etc.) to select, move and resize graphic objects (Mark and Gould 1991). This approach gives the user a great deal of control and

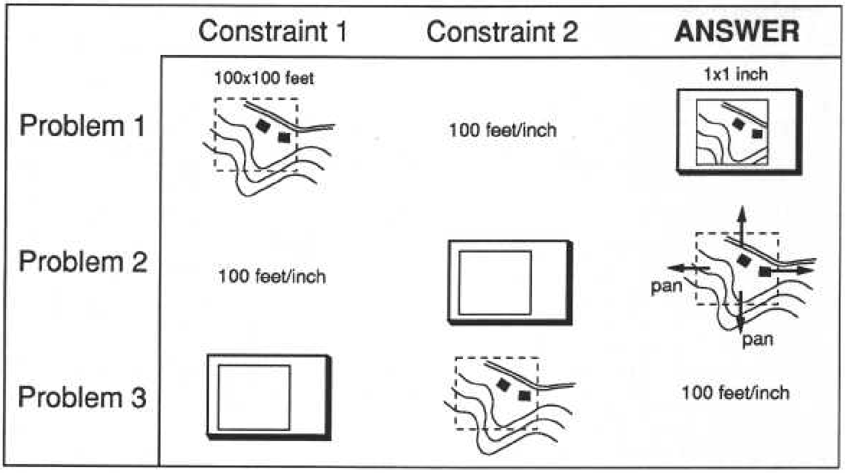

Figure 1: Common Extent/Scale/Size problems in map layout

flexibility, as they perform actions and receive instant feedback on the consequences of those actions.

For large maps, direct manipulation is difficult to utilize because of the relatively small dimensions of even 'large' workstation displays. Also, direct manipulation is not always optimal for fast production of many maps with similar, but slightly different, dimensions.

As part of the General GIS Interface (GGI) (Crane 1993; Ganter 1993a and b), we decided to build a control panel that would allow the user to calculate, manipulate, and constrain the variables of Extent (dimensions on the ground), Scale (e.g., feet per inch), and Size (dimensions on screen or media) in an interactive and iterative manner. We thought that such an interface might improve the user's conceptual model of the subtle relationships between these variables and their practical consequences in map layout. It would also free time for other tasks, including the more aesthetic aspects of map design.

EXAMPLE PROBLEMS

The Calculator panel assists the GIS user in solving three common problems (Figure 1):

(1) Given an Extent on the ground, and a definite Scale, what is the Size of the resulting map? Example: several buildings must be shown, the Scale must match engineering maps; can output be laser printed or must it be plotted?

(2) Given a fixed Scale and map Size, what Extent on the ground can be shown? Example: The Scale must match 1:24,000 topographic quadrangles and the map must fit on letter-size paper. What size zone can be shown

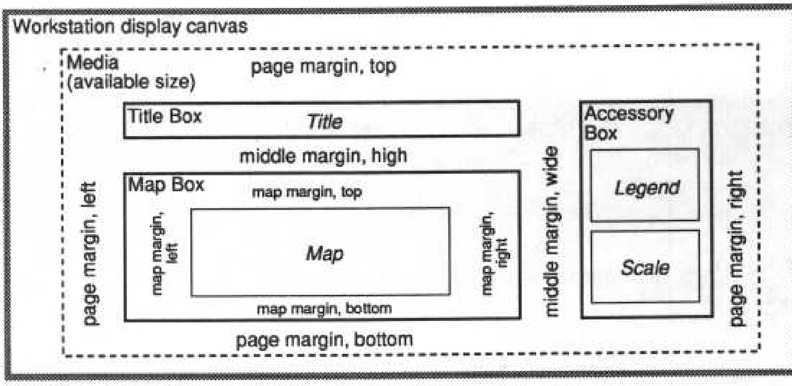

Figure 2: Map layout template

around the feature of interest?

(3) Given a fixed map Size and Extent, what is the Scale? Example: a facility must be completely shown on letter-size paper; what is the Scale? If a decimal results, the user can round it up or down to a large round number as desired, and test the result in (1) or (2) above. For instance, a user would probably round 96.7 feet per inch to 100 feet per inch.

A manual approach to solving these problems could involve many steps, especially if the layout includes legends and other accessories. For instance, in a variation of Problem 3, the user might have roughly 6 inches available in width, 4 inches in height, and an extent of 400 feet wide by 500 feet high. Scratchpad calculations would follow:

$Scale_{width}$	=	400 / 6	=	66.66 feet per inch
$Scale_{height}$	=	500 / 4	=	125 feet per inch
$Size_{width}$	=	400 / 70	=	5.7 inches
$Size_{height}$	=	500 / 70	=	7.1 inches
$Size_{width}$	=	400 / 125	=	3.2 inches
$Size_{height}$	=	500 / 125	=	4.0 inches

By doing a sequence of such calculations, and then entering the results into the GIS and observing the appearance of the display, the user can eventually come up with a satisfactory layout. The user might also set up forms of the equation in a spreadsheet to aid this experimentation.

We decided to extend the spreadsheet idea into a kind of specialized 'Calculator' linked to the graphic display in two ways. First, the Calculator would control the display; typing in a new extent would change that extent in the display. Second, manipulating the graphic display (e.g., by zooming in) would change the Calculator values. The user could also *lock* certain values in the Calculator that they wished to preserve, thus forcing the Calculator to change the way it solves the equation.

The Calculator can be considered a *visual formalism*. Visual formalisms are defined as "diagrammatic displays with well-defined semantics for expressing relations" (Johnson, et al., 1993). Visual formalisms in user interfaces are control panels, expanding trees, schematics, etc. that use widgets (buttons, readouts, sliders, dials) in arrangements that conform to user's knowledge and expectations. Calculator benefits from three general qualities of visual formalisms (Johnson, et al., 1993):

- VISUAL COGNITION: humans have both innate and acquired skills in recognizing and inferring abstract structure from spatial relationships such as proximity, linearity and alignment;

- FAMILIARITY: they are part of everyday life, so people become adept at recognizing similarities and experimenting to figure out how they operate;

- MANIPULABITY: they are dynamic, changing and reacting to both reflect and constrain user actions.

These general characteristics suggested that we could design a panel with a high density of changing data, and that users would be able to discern basic structure and function from their past experiences with everyday objects like calculators, tables, and spreadsheets. We hoped that the Calculator would aid the user in learning, enhancing, and applying a conceptual model of the extent/scale/size equation. The Calculator would provide feedback to either solve a layout problem immediately, or encourage experimentation that would reveal one or more design solutions.

DESIGN AND LAYOUT OF PANELS

As mentioned, the Extent/Scale/Size calculation outlined above must be extended somewhat to handle more complete layouts where the map is surrounded with titles and legends. We control these cartographic devices as 'Boxes' in a standardized template (Figure 2), the dimensions of which the user can modify. The user can experiment with various Box sizes and the margins between them to alter the overall appearance and dimensions of the

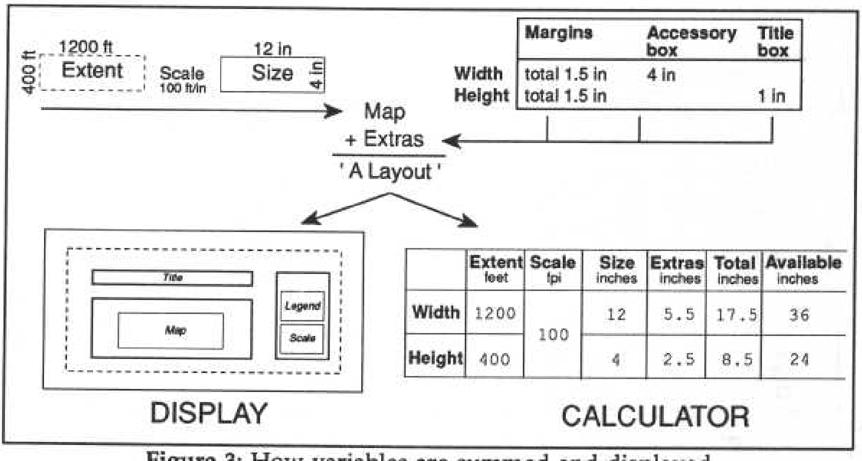

Figure 3: How variables are summed and displayed

map. We sum all of the space consumed by these *Extras* (margins and Boxes) in the horizontal and vertical dimensions, and display these sums in the Calculator (Figure 3).

The user is thus assisted in calculating a map Size (Figure 3, top left) that is combined with Extras to produce results (a total Size) on both the graphic display (Figure 3, left) and the Calculator panel (Figure 3, right). The user can see how the Extras contribute to the Total layout size and how this compares to the Available dimensions of the currently selected output device.

Our overall interface uses the analogy of a camera which is directed by the user at places of interest. The Calculator (Figure 4, bottom) can be thought of as controlling the magnification of the camera lens. The user clicks 'Lock' buttons to choose which variables are the 'constraints' (see Figure 1). For

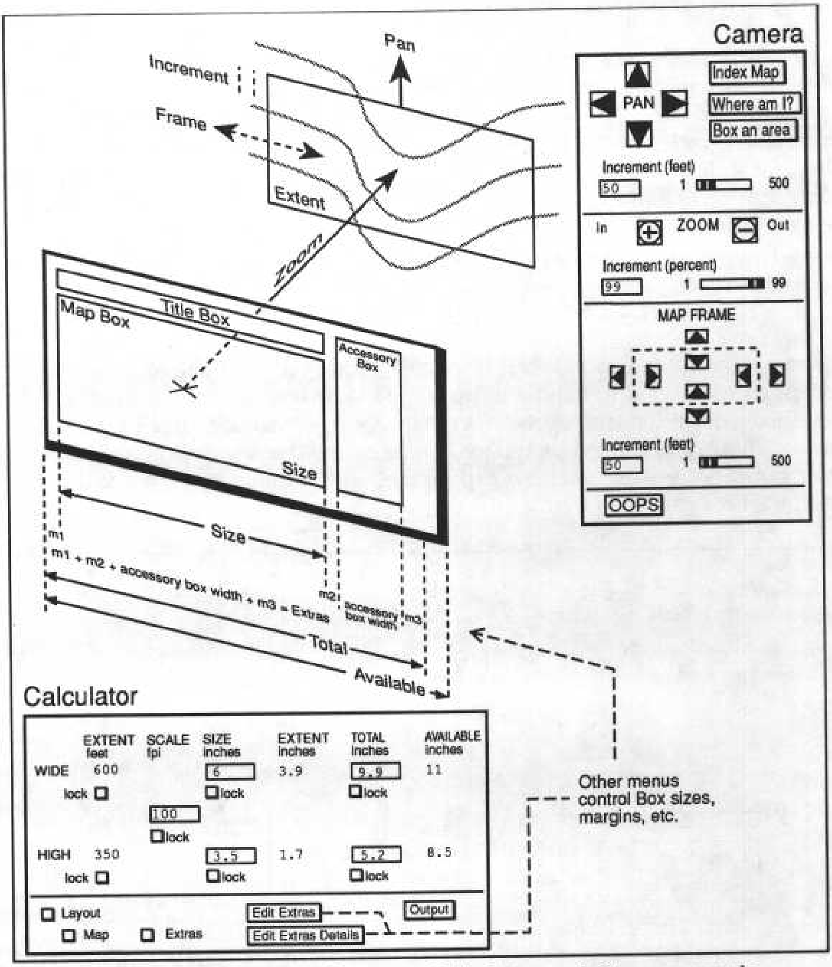

Figure 4: Relationship between Calculator and Camera panels and the map layout

example, to solve a problem of fixed Extent and fixed Scale, three Locks (Extent height, Extent width, Scale) would be depressed and the Calculator would then report the Size.

Continuing with the camera analogy, another adjacent panel controls pan, zoom, and framing (Figure 4, right). Panning merely moves the camera lens: it has no effect on the Calculator. Zooming is closely linked to the Calculator and can affect Extent, Scale or Size depending on the status of the Locks. For example, if the Extent is locked then the user is not permitted to Frame.

(Each Camera control has sliders that control the increment: the amount, either in units or percentage of the screen, of movement for each button press. The panel also contains several loosely related buttons. Index Map shows the initial 'start-up' view; the whole Extent of the present database. Where am I? temporarily zooms outward and draws a box around the current Extent. Box an Area is a form of zoom where the user draws a box, using mouse and cursor, around the area of interest. Oops is an undo/redo feature that cancels/uncancels the last action.)

At the bottom of the Calculator are two buttons, Edit Extras and Edit Extras Details, that control the detailed dimensions that combine into the Extras totals. Edit Extras is more frequently used and brings up a panel for controlling margins and the sizes of the Title Box and Accessories Box. Edit Extras Details is less commonly used, and allows some control over the internal characteristics (e.g., fonts, line weights, colors) of Boxes. More control is expected in future versions, so that the user can modify the parameters of the algorithms that perform a 'best fit' of the legend, scale, etc. in the Boxes (Ganter 1992).

Another button on the Calculator, Output, brings up a panel (not shown) where output device and media dimensions and orientation are chosen. This panel influences the Available inches readout that is displayed on the Calculator.

At the bottom left of the Calculator panel are three buttons that control the manner in which the map and extras are shown on the display canvas. When Layout is toggled off, the current Extent fills the available screen space. This is ideal for simply browsing data, typically by using the Camera control panel. When Layout is toggled on, the display canvas reflects current Size. For example, if the Size is 30 inches, the user will see 30 inches drawn to scale as a miniature (and unreadable) map. In this Layout view, the user can choose to see the map, the Extras, or both. This feature is useful during the iterative process of designing a layout, since it allows the user to concentrate on one or the other without waiting for the entire screen to redraw.

EXAMPLE OF USE

The user can interact with the Calculator both by typing values into the readout spaces, and manipulating the Camera panel. As a result, the Calculator readouts are very dynamic but can be constrained by the Locks. The user is notified of invalid operations (e.g., attempting to Frame when the Extent is locked), and the system suggests appropriate actions though pop-up message boxes.

Figure Sequence:

┌	button up (off)	KEY
┘	button down (on)	

5 The user views a number of polygonal features. The Extent, Scale and Size are visible on the Calculator.

6 Using the Box an area button on the Camera panel, the user has zoomed in to view two polygons. The user has also changed the Scale to 90 feet per inch, and locked both this scale and the Extent so that they will not change. The new Size is displayed, and the Extras, while not shown, are calculated.

The user then decides to set the Total size to 10.5 inches, in order to more completely fill the Available media. They enter and lock a Total width of 10.5 inches. This additional space must now be dealt with.

7 The Allocate menu appears automatically. The user is told that there is 0.5 inches available. This space can be used in the Accessories box, or various margins.

8 The user increases the Accessories box width from 2.4 inches to 3.9 inches, thus consuming the extra space. The new Extras and Total inches are displayed. The Layout button is toggled, so that the complete Layout (map and extras) is now drawn.

THE CALCULATOR EVENT LOOP

AML menus allow the programmer to construct an interface with a few high-level function calls under which the details of the low-level X11 graphical operations are hidden. These menus are event-driven. Their normal state is 'at rest' displaying the status of global variables (e.g., an Extent value or Lock status), while waiting for an 'event:' a mouse click or keyboard entry.

When an event occurs on Calculator, a series of tests and calculations are performed that check the validity of the event, the context in which it occurs, and the effects on other variables. The event, if valid, disturbs an equilibrium in the equation [Extent / Scale = Size]. The equilibrium is then restored by propagating changes to all the affected variables and redrawing the screen.

The general steps in restoring this equilibrium are as follows:

(1) The menus display the current values of variables and locks.

(2) The user presses a button on the Camera panel (e.g., Zoom), or types a new value in Calculator.

(3) Step 2 produces an instruction to process specific variables. A program takes this instruction, checks it for validity (e.g., Zoom is not possible if the Scale or Extent are Locked). The program then requests information on the

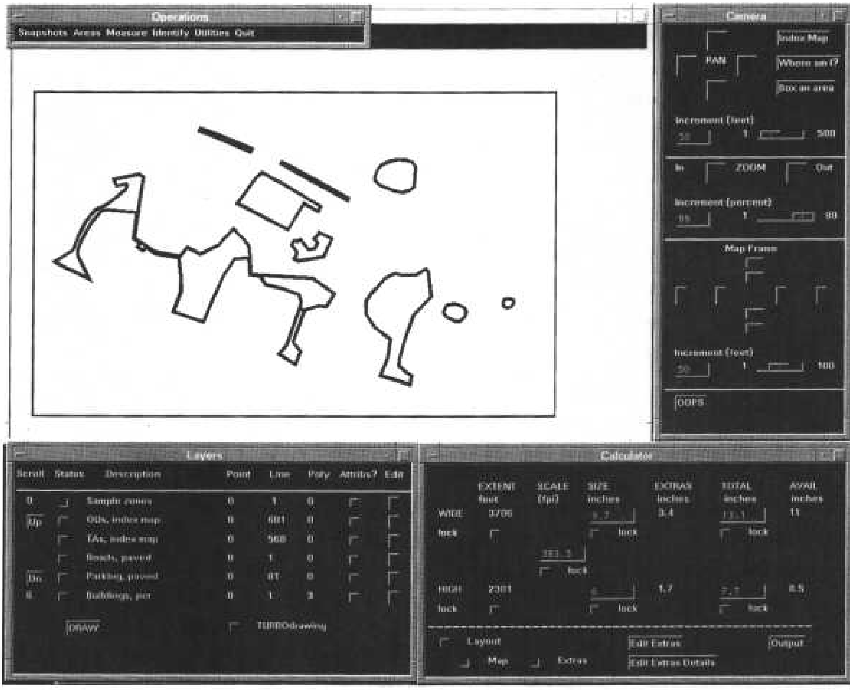

Figure 5

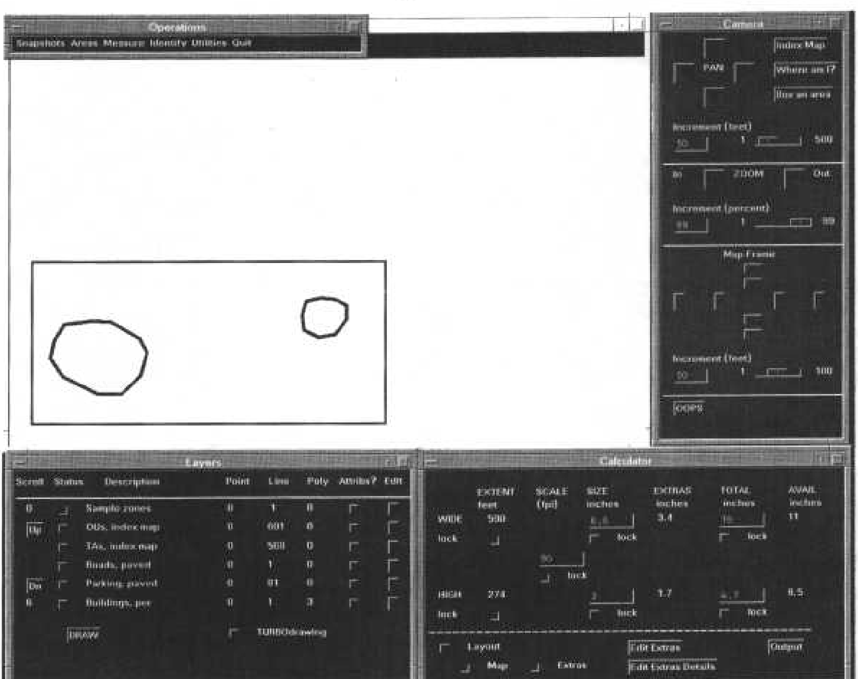

Figure 6

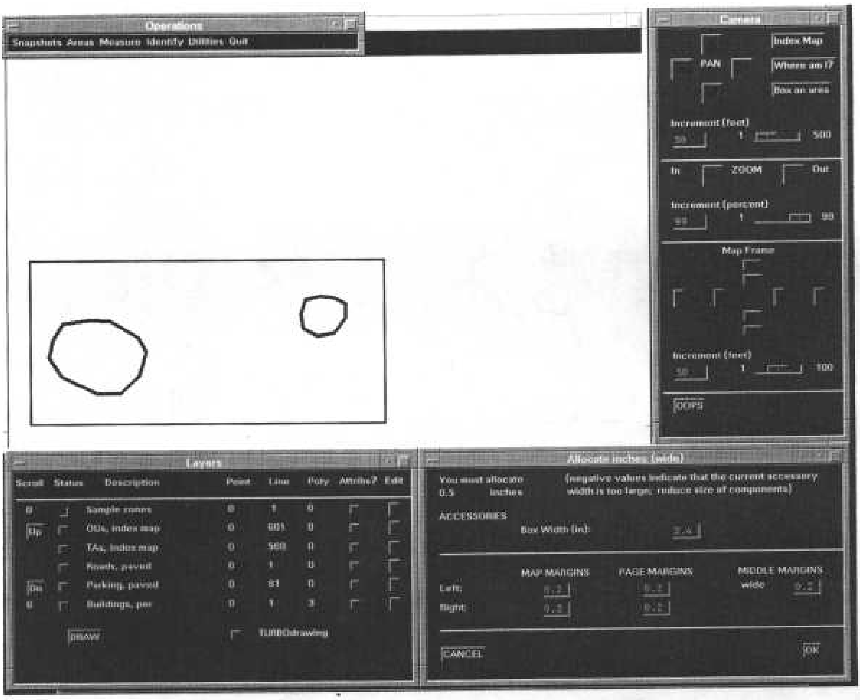

Figure 7

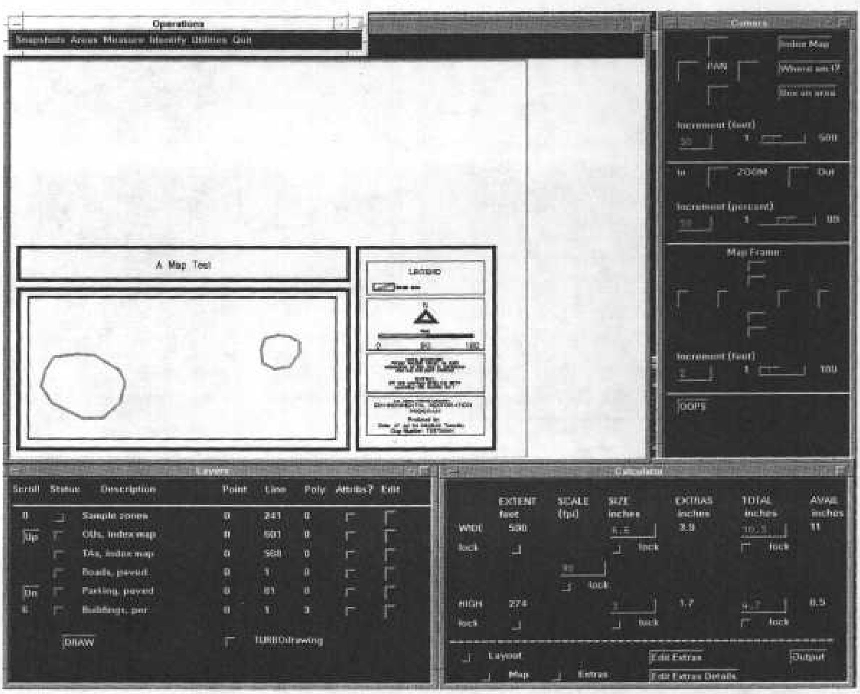

Figure 8

form of the equation to solve and the calculations that are necessary.

(4) A subroutine concatenates the original instruction with a binary string that represents the status of the seven Locks. This complex state is matched to an entry in a lookup table to determine which calculations to perform. There are over 100 distinct combinations of instructions and Locks in the lookup table.

(5) The calculations are performed, and the new values are propagated to all affected variables. Equilibrium is restored, and Calculator awaits the next event.

CONCLUSIONS

Calculator seems to support the visual formalism concepts of using innate visual cognition, familiarity, and manipulability. Our test users were able to grasp the operation of Calculator, and felt that it behaved like a somewhat unusual spreadsheet. In learning to use Calculator, it was useful to let it simply 'freewheel' with all Locks turned off while various Camera operations were carried out. By observing the behavior of Calculator while doing simple pans, zooms and frames, users developed a grasp of the variables it was showing and how they could influence these directly. Calculator also proved to be oddly complex at times, and it is possible that simplifications, additions, or even a completely different approach would be more illuminating for the user.

At present, Calculator requires the Scale to be in feet per inch. This is a useful and intuitive form for large scale maps, but the user should have the option of using ratio scales (e.g. 1:24000), and metric units.

The use of templates for layout, and the presently limited control of those templates, may seem rigid but it does support the rapid production of generic maps. This can free time for pursuit of more creative options using other tools, e.g. Arc/Info Map Composer, or drawing packages. The Calculator is a key to this intermediate *draft map generator* between GIS data and final cartographic production.

The menu functions are a significant addition to AML that makes rapid prototyping of concepts like the Calculator possible without low-level programming of the X11 graphical user interface. However, at the current version there is limited control of panel layout and graphical elements. For instance, it is quite difficult to precisely align widgets, and to draw lines and separators. It would also be useful if the readouts could be 'flashed' to alert the user to a new result or required entry.

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NOTE

1. By convention, the scale of a map is based on the ratio of map distance / ground distance. A 1:100000 map is thus "smaller scale" than a 1:24000 map, but it shows a larger area.

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