The Visual Computer

The Globall Hyperatlas: a development proposal

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A future hardware system designed to support an interactive geographic database is outlined. The basic system is intended for domestic and educational use and extensions of the system are foreseen as serving a wide variety of professional users. The main physical and functional parameters of the system are presented. Possible problems are indicated and development goals are suggested. The aim of the paper is to initiate a detailed and informed discussion about how such a system may be developed.

Key words: Computer-aided learning – Future trends – Geographic databases – Hardware development philosophy

1 Motivation

The visual enrichment of human experience is a major benefit of computerized imaging technology. In many fields this enrichment needs to be disciplined and made interactive, for example by developing dedicated educational systems for future generations of students. One wide and rather important area where visual experience can be more systematically acquired using foreseeable technology and information resources is that of global awareness and Earth-related knowledge.

Geography, expanded to include the Earth sciences such as geology, plate tectonics, and climatology, as well as parts of history such as the growth of human communities, exploitation of natural resources, and the territorial expansion and decline of empires, lends itself well to a highly visual mode of presentation. Furthermore, this mode can be made highly interactive with numerous branching choice paths forming a vast hypermedia tree of possible experiential adventures. [On the educational use of hypermedia see Jonassen and Mandl (1990)].

The essential novelty in the proposal outlined here is an electronic globe, a "Globall". Remotely controlled by a hand-held trackball, this globe is programmed to show the Earth as it appears from space, with clouds and a day/night boundary, and may be driven to show weather patterns and seasonal changes. Linked to a suitable database, it can display ultraviolet, infrared and radar images, topographical and climate contours, mineralogical and population data, and the evolution of various phenomena over a wide range of timescales. Linked to a high-resolution monitor, it allows the user to zoom in on a chosen area and explore small-scale features and access any amount of background data about particular places or features. Linked to a global data network, the globe can be used to access real-time data on weather conditions or traffic movement or even to access a global hypermedia news service with news located and scaled to fit the chosen zoom area. The globe is a natural user interface for all such purposes.

2 GH hardware

2.1 The Globall

Given the present state of display hardware technology, an electronic globe with reasonable size and surface resolution is not yet a feasible device.

Cathode-ray-tube technology does not readily allow the creation of a uniformly scanned image from within a spherical surface, and liquid-crystal bitmap displays cannot yet be made big enough to form a useful globe. Megapixel CRT displays already exist for high-definition television, but bitmapped megapixel liquid-crystal color displays are still some years away.

A globe should be as large as possible, both for maximum general impact and for maximum surface resolution. Practical size constraints are cost and portability. Larger globes are more expensive both because they incorporate more material and because they have smaller markets. A mass-market globe must be small enough to pass through doorways and fit on desks. Furthermore, the scale of a globe should be chosen to be as simple a ratio as possible. A scale of 20000000:1 gives a diameter of 64 cm, which is a reasonable size (Fig. 1). With a base cutout 25 cm in diameter this gives a pixelated surface area of about 1.23 m^2. A line resolution of four color pixels mm^{-1} is enough to give an image as sharp as an HDTV screen 30 cm high and to require bitmap power lines with widths on the order of 100 μm. This is well within the range of contemporary lithographic techniques. However, the total of about 20 million pixels implies that manufacturing such globes is beyond present technology.

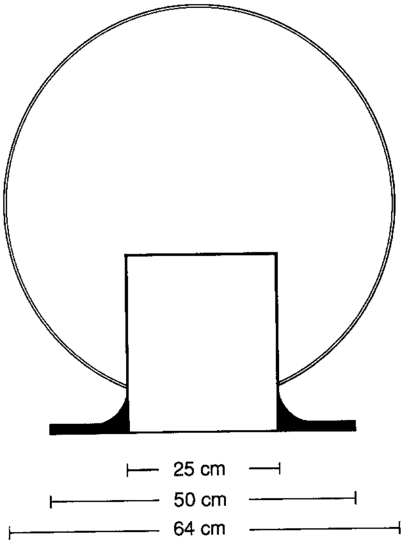

Fig. 1. The Globall (vertical cross-section)

LCD technology may not be optimal here. It may not be possible to achieve sufficiently high or uniform image luminosity using a backlit LCD system. It may prove more satisfactory to use new microcathode technology, which is still about ten years from industrial implementation (*Scientific American* 1990). Cold-microcathode technology shares the LCD advantages of allowing bitmap displays of arbitrary size and shape, for example large and spherical, and operating at room temperatures with power supplied at low voltage. The microcathode arrays are manufactured using standard VLSI lithographic techniques, and blocks of several hundred together are used to activate each color dot in a pixel. With power supplied at 50–80 V, the microcathodes emit electrons that travel only about 200 μm across an evacuated gap before hitting the dots, so that no steering or focusing electrodes are needed. It is still unclear whether or not LCDs will eventually be superceded by such microcathode arrays.

The Globall needs a robust base, say 50 cm in diameter. The base collar supporting the glass envelope should be narrower, say 25 cm in diameter. This size is motivated. The Earth rotates on its axis, and its axis makes an angle of 409 mrad with the normal to the plane of its orbit around the Sun. The axes of all traditional "dumb" globes are tilted at this angle of 409 mrad to the vertical. It may be appropriate to set the default orientation of the Globall image at this angle. With a collar diameter of 25 cm, the South Pole of the default image is located about 1 mm clear of the collar. Thus, a collar diameter of 25 cm is the largest to meet the sensible criterion that as the default image rotates, no part of the image is permanently occluded by the base.

The Globall should be capable of functioning as a standalone device, without a zoom monitor, keyboard, disk drive, or network connection. To support a minimum level of functionality, it will therefore incorporate some inbuilt electronic hardware including enough ROM for an image minilibrary; enough processing power to roll, spin and evolve a 20-megapixel image at 25–30 frames per second; decoding circuitry for an infrared sensor to read the hand control; a buffered power supply; and possibly also a cooling fan. A cylindrical tub set in the base and projecting 15–20 cm into the interior of the Globall provides 10–12 l of volume for this hardware. Because most of the interior of the globe is empty space, most of the Globall's mass is concentrated in the base hardware. Thus, the hardware serves as ballast to prevent the globe from rolling over. An infrared sensor is built into the outer rim of the base and segmented to sense the direction of the hand control.

2.2 *The hand control*

The Globall is intended for use not only by experts seated at the zoom monitor keyboard, but also by children, casual viewers, and by walking/talking teachers. Therefore, it requires a hand control that does not intimidate the user and that offers freedom together with basic control options (Fig. 2). This hand control may be a battery-powered device that communicates with the Globall via a one-way infrared link. The keyboard of the zoom monitor remains the interface for serious dialog with the Globall and includes all the items on the hand control, but these are overridden by the hand control whenever it is in use.

The central feature of the hand control is the trackball. Rolling the trackball rolls the image on the Globall. Above the trackball is a rotating control called SPIN, which sets the image spinning about its axis in the orientation set by the trackball. The spin rate may vary from zero to perhaps ten days per second, so that the passage of the seasons and long-term weather patterns may be studied.

There are two keys, SKY and DAY, to the left of SPIN, and two keys, NORM and HOLD, to the right. SKY gives an image complete with clouds or an image without clouds, depending on the current image. DAY gives an image with a dark half or a uniformly lit image, again depending on the current image. NORM normalizes the image to a uniformly lit, cloudless view with the axis tilted at 409 mrad to the vertical and the North Pole uppermost, whatever the previous image. HOLD is for use in conjunction with DAY and SPIN and holds the image fixed while the dark half spins around it; this allows the viewer to see changing cloud patterns and the seasonal advance and retreat of snow and ice cover.

Below the trackball is a rotating control called ZOOM. There are two keys, SPOT and ROLL, to the left of ZOOM and two keys, KEY and ON, to the right. SPOT causes a small flashing point, a flashpoint, to appear on the image at the position on the waistline of the globe which directly faces the handheld control unit (Fig. 3). The trackball now moves the flashpoint instead of the image. ROLL causes the trackball to move the image instead of the flashpoint, in case this is more convenient. If pressed a second time, it causes the trackball to revert to moving the flashpoint instead of the image – without zipping the flashpoint back to the waistline SPOT location. Rotating the ZOOM control counterclockwise causes a bright

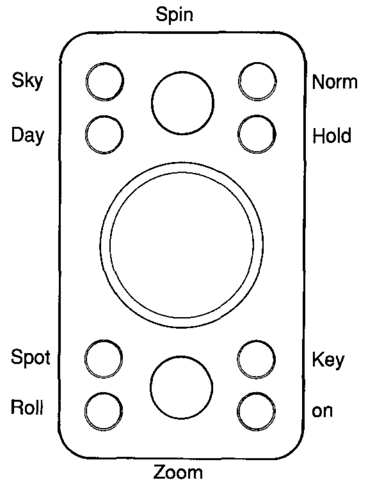

Fig. 2. The hand control (top view)

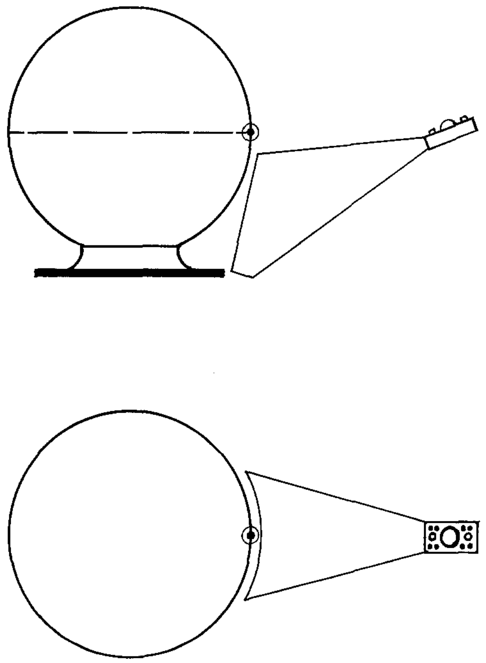

Fig. 3. SPOT flashpoint location

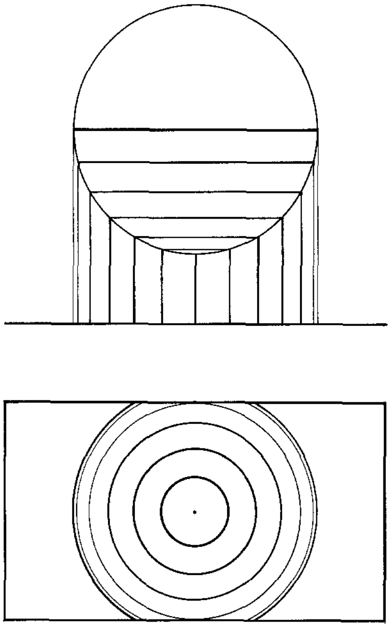

Fig. 4. Projection of zoom monitor image

rectangular outline to expand from the flashpoint. When the Globall is connected to its zoom monitor, the outline corresponds to the monitor screen and indicates the area represented in the screen image. The rectangle geometry is defined by rays parallel to the radius through the flashpoint and distorts the screen image when the rectangle covers a large area (Fig. 4). The distortion has circular symmetry about the center of the screen and squashes the image radially near the screen corners. Other projections are possible, of course, but they are less intuitive. The ZOOM function cuts off in the counterclockwise direction when the rectangle height becomes equal to the globe diameter.

The KEY key returns control to the monitor keyboard, if it is connected. All sophisticated globe displays are handled through the keyboard. The ON key switches the hand unit on and off, and also switches the Globall on and off if a keyboard is not connected.

2.3 The Hyperatlas system

The basic Hyperatlas system consists of a Globall; a hand-held control; a zoom monitor with a megapixel flat screen, perhaps in HDTV 9-by-16 format; an image-driver box that may reasonably be expected to pack substantially more computational power than a present-day isolated graphics workstation; a standard keyboard supplemented with a trackball and the other items on the hand control; and a CD-ROM reader, perhaps with a multidisk jukebox configuration, to extract data from compact-disk databases. The CD-ROM reader may be built into the image-driver box, and the box, zoom monitor, and keyboard may be linked by cables (Fig. 5).

Without the rest of the Hyperatlas system and a library of compact-disk databases, the Globall with its hand control alone is not much smarter than a "dumb" globe. The real utility of the system lies in its ability to display a large number of geographic locations and represent a large amount of geographic information more directly and intuitively than any system not based on an electronic globe. Already at the computationally elementary level, locations can be identified using the flashpoint and the zoom rectangle on the globe and instantly named or described on the monitor; conversely, names, coordinates, or descriptions can be input at the monitor and instantly located or illustrated

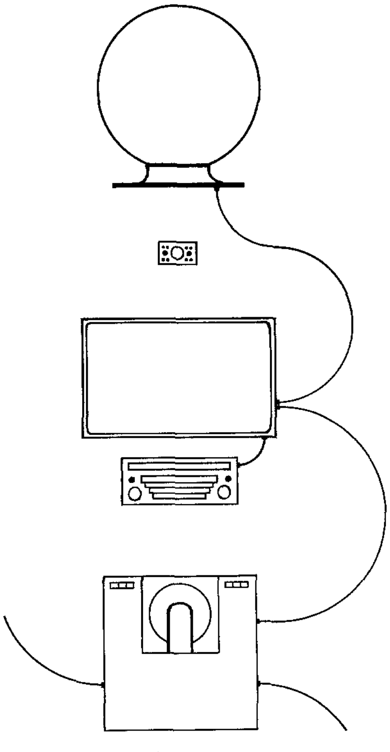

Fig. 5. GH system hardware

on the globe. In this way, a database corresponding to the index of a conventional printed atlas can be quite routinely implemented.

In addition, thematic atlas maps of rainfall, temperature, population, and so on can easily be imaged on the globe and commanded by simple keyboard inputs. Annual variations in the imaged variables can be represented directly by the evolution over a few seconds of the global image. [The design of thematic maps is discussed in Yamahira et al. (1985) and the production of population maps in Browne and Fielding (1987)].

It would, of course, be technically possible to build a high level of intelligence into a 21st-century system of this sort. However, for the basic mass-market system it is likely to be too expensive to implement, say, extensive dialog capability or voice control or virtual-reality interaction with zoom landscapes. With a suitable library of disks, the basic system user could already do such things as call up a street map of any chosen city, locate mineral or ocean resources on a planetwide basis, view a correctly spherical projection of commercial long-distance air routes, call up an image of the global cloud distribution as it was, say, on Thanksgiving Day in the year 2010 and find out if it rained in New York City on that day, study the thinning of the ozone layer and the melting of the polar ice caps, and so on. The range of possible datadisks, and hence of new ways to use the system, is limited only by time and human imagination.

The time limitation is obvious. Even a highly developed disk recording and distribution system cannot cut the cycle time from data capture to consumer delivery sufficiently to enable the standalone system to function, say, as a global weather data access point or a global news monitoring terminal. A basic Hyperatlas system would need to be plugged into a network to serve these purposes. Also, access via networks to data stored in centralized disk libraries may be more economical than buying or renting disks. It seems certain that such networks will be developed as soon as Hyperatlas systems come into widespread use.

3 GH functionality

3.1 Globall functions

The Globall is an expensive piece of hardware designed to perform what is essentially a single function, namely to represent planet Earth in its various aspects. The question arises of whether a standard multifunction flat screen can perform this function well enough to make the Globall redundant.

The answer is that a flat screen cannot make the Earth image vivid and real enough to catch the imagination, especially the young or the popular imagination, so well. Our planet is almost exactly spherical, with an equatorial radius of 6378 km and a polar radius of 6357 km, so a globe of (internal) diameter 63.7 cm is accurate in overall shape to ±1 mm. Surface bumps on the Earth are all less than 9 km above sea level, which corresponds to 450 μm, the size of two pixels. The Globall is not just an imaging device, but a precision scale model. This fact alone may be considered sufficient to justify its manufacture.

The logic functions built into the Globall are basic. Rolling and spinning the image, moving clouds across it and darkening one half are all computationally elementary. However, there are fine details that require some care. For example, acquiring accurate cloud data is a nontrivial problem. Satellite images cover limited areas and need to be spliced together synchronously and smoothly to generate useable databases. Simulation may serve to fill gaps, but supercomputer simulation of atmospheric circulation is still a very approximate business. Hence, building cloud databases will require a major effort.

Seasonal patterns pose further problems. Polar ice caps and snow on mountaintops advance and retreat with the seasons, and accurate global databases for these changes will need to be assembled. Vegetation also advances and retreats with the seasons and gives rise to visible changes at the Globall scale. Ocean currents and aquatic biomass can change the color of Globall sea patches.

Even the dark half is not simple. The twilight zone needs to be accurately modeled, with lengthening shadows for mountain ranges and subtle color effects due to atmospheric refraction. Also, it may be worth modeling big city lights. Lunar illumination, solar eclipses and the Northern and Southern Lights are perhaps best left as modeling exercises for enterprising hobbyists.

The flashpoint and zoom features do not pose major programming problems for the Globall itself. However, it may be worth offering the facility to represent the zoom monitor image directly on the Globall surface. This would be useful, for example, in a classroom if not all the students could see the monitor screen.

3.2 Hyperatlas functions

Coding maps from global and local atlases and ordering them by increasing scale to generate a smooth zoom function is a straightforward computational task. Choosing features of interest for various applications and representing them in a visually compelling way is also computationally straightforward. Optimizing transitions between different applications poses deeper problems. Cutting from a visual map to a geophysical map, then to a temperature map, and then to a land-use map may require vast amounts of data to be accessible in parallel, and changing disks manually to implement each such thematic cut may be unacceptable. However, this is not a computational problem unless the system is required to be intelligent enough to anticipate likely data calls and line up the data in advance.

A more theoretically interesting problem is that of labeling extremely heterogeneous masses of information so that they can be called without too many keystrokes. Here a certain amount of system intelligence is required. The zoom-scale hierarchy is likely to define a tree of interrogation paths with multiplying branches giving detail on increasingly numerous aspects of an area at increasing scales. A series of menus may provide an acceptable access mode for some purposes, but for a large database a more direct means of access via short natural-language instructions seems preferable. Also, a window system for displaying simultaneous nested zoom views would be useful. Here there is scope for a good deal of research and for new software incorporating deep and computationally nontrivial innovations.

The Hyperatlas system can offer more than mere maps, but just how much more may not be obvious. Zooming in on a city may give access to street maps, public transportation maps, telephone directories, views of famous landmarks, advertisements for various businesses, biographies of local personages, and so on. Hypermedia trees of this sort have the potential to continue branching practically to infinity, and it may require real self-discipline from the system developers to resist the temptation to allow their tree to grow into a universal encyclopedia.

3.3 Further options

Further hardware options for the GH system are not difficult to imagine. The keyboard may be replaced or supplemented by an electronic slate or a voice-input facility. The zoom monitor may be replaced or supplemented by a virtual-reality helmet with a zoom facility approximating the phenomenology of spaceship re-entry. And the compact-disk reader may be replaced or supplemented by an intelligent mapreader that can animate scanned maps in real time, or by a superintelligent text reader that can do the same for travel books.

More prosaically, the Globall itself can be used to image the surface features of other heavenly bodies. Modeling the Moon is a fairly straightforward challenge, given enough pictures of its far side, and modeling Mars is not much more difficult. Modeling the surface of Venus may be an interesting exercise, and picturing the atmospheres of the outer planets may create decorative displays. [Animation of extraterrestrial zoom views to accompany such displays is discussed in Holzman (1986)].

More theoretically interesting is the challenge of building mathematical planetary surfaces using fractal landscape modeling. A competition might be held to find the simplest fractal algorithms that can approximate the coastlines and surface topography of the Earth up to the resolution limit of the Globall.

A serious and potentially very large astronomical application is to use the Globall as an astrosphere to represent the night sky with all its stars and galaxies. The SPIN function can be accelerated to display planetary motions, and a new turning control can be incorporated to increase the brightness of the image and thus bring more remote objects into view. Together with the ZOOM function this simulates the imaging capability of an astronomical telescope. Astronomical databases for this application could be arbitrarily large. However, a modest compact-disk library together with suitable explanatory software could form an excellent educational and hobby package.

4 GH project organization

A GH development project requires the leadership of a major computer or electronics manufacturer. Development costs of tens of megadollars can be anticipated for the Globall alone, and perhaps hundreds of megadollars for the full Hyperatlas system, including libraries of datadisks and related network facilities.

A market for the system exists. The educational sector alone can absorb millions of units planetwide, and the domestic market can absorb tens of millions as soon as unit costs begin to sink. Thus, gross turnover in the GH industry can quickly reach the billion-dollar level. The risk involved appears to be no greater than normal for a project of this sort.

The hardware developments presupposed for the GH system are not very exotic. Large bitmapped high-resolution arrays will be developed independently of the GH project, and most of the GH system hardware consists of standard multipurpose items. The greatest hardware challenge is to construct high-resolution arrays on the inner surfaces of large glass spheres with access only via small cutouts. This will require the development of specialized robot manufacturing systems. Otherwise, the hardware aspect appears to present no great obstacles.

The software aspect is more challenging. Essential to the entire project is the availability of imaging and visualization software that can make full and creative use of the hardware capabilities. Most of the imaging and visualization ideas presented above appear to be feasible with only modest extensions of current capabilities, but some of the ideas are clearly speculative.

The information resources needed to put the GH system to good use pose another set of problems. Standard printed atlases supply much of the background information needed, but a comprehensive library of satellite images is also needed to program the basic Globall view-from-space animations. A recent project to build a "dumb" globe modeling the Earth as it would appear from space if there were no cloud cover required a massive computer splicing effort involving 37 million NASA satellite images. [The project, reported in *The Sunday Times* (1991) and mentioned in *Discover* (1991), led to the formation of the GeoSphere Society]. The basic Globall images will require a much larger effort.

System hardware, imaging software, and information resources all need to be developed beyond present levels. However, the development of appropriate imaging software is the key to the feasibility of the entire project. Only when it is known that the information can be imaged in the anticipated way on the given hardware can commercial companies start to invest large sums in the GH project.

5 Proposal

The opportunity now exists for specialists in the field of imaging and visualization software and systems to make a fundamental contribution to the GH project. Their expert advice at this exploratory stage is required to assist in evaluating the possibility of launching the project in the near future.

The author humbly proposes that the members of the Computer Graphics Society are well qualified to make an evaluation of the feasibility of the Globall Hyperatlas system and to participate in the eventual formulation of a detailed development plan.

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