HyperMap: A GEOGRAPHICAL INFORMATION SYSTEM FOR IMAGERY AND TEXT STORAGE AND RETRIEVAL

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ABSTRACT

A geographical information system for storing and retrieving imagery and text data is described. The system provides a flexible means for attributing geographical features using full-text indexing and retrieval techniques. It integrates content-based and spatial data access methods into a single environment. The system is easy to use and involves no programming on the part of the user. All data is stored in standard Macintosh file formats. The system represents a low cost means of organizing and accessing imagery and text data for remote sensing and GIS applications on a standard color Macintosh with hard drive.

1. INTRODUCTION

A variety of remote sensing and GIS software packages exist for managing imagery, map bases, and feature attribute data. Current systems provide limited mechanisms for accessing data, e.g., by means of structured query languages and relational databases. Future trends appear to be leading towards hypermedia systems capable of handling imagery, graphics, text, audio, and video data in a seamless fashion. This paper describes a prototype system known as *HyperMap* for organizing imagery and attached free text data in a geographical or spatial context. A prototype has been implemented in Common Lisp on the Macintosh and used to support several remote sensing projects. Several key features of the system are:

- Flexible means for feature attribution using full-text indexing and retrieval techniques
- Integration of content-based and spatial data access methods in one environment
- Involves no programming on the part of the user and uses standard Macintosh file formats
- Low cost - requires standard color Macintosh with a hard disk drive

Section 2 outlines several application areas for which the *HyperMap* concept is uniquely suited. Section 3 provides further details on the system with particular attention to the organization and representation of geographical information, methods for accessing imagery and text data, and novel presentation techniques for imagery and text data. A case study which demonstrates the key features of the system is presented in Section 4. Section 5 outlines future work.

2. MOTIVATION

The need to organize and access imagery and free text together arises in many applications. For example in remote sensing, it is often necessary to develop collateral databases which organize ground truth information such as digital/digitized photography, field reports, and other data. These data are then used to assess the performance of remote sensing techniques, e.g., by displaying coregistered satellite imagery, processing results, and maps along with the ground truth. The prototype described in this paper was motivated largely by this kind of application.

In image database systems, imagery is generally indexed by a fixed record structure which describes image acquisition conditions, image quality, and other salient parameters. In some situations it may be desirable to access imagery by a description of its content. If free text descriptions of objects, events, or characteristics of the imagery are available, by associating the text with the imagery, interactive image browsers can be developed for searching image databases by content. The *HyperMap* concept is well-suited to such applications particularly where the data are geo-referenced.

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A third area of interest is geographical information systems. By indexing geographic features by free text attributes more general search strategies for GIS can be implemented. As a domain changes and new attributes become of interest, they can be added to the database without having to reindex older data. Texts which may be difficult to format can be ingested and indexed *in toto*. To find a particular kind of geographic feature in the database one can query by one or more key word attributes. Similar objects can be found using query-by-example by matching the content of entire texts, retrieving those that are "closest" to the query.

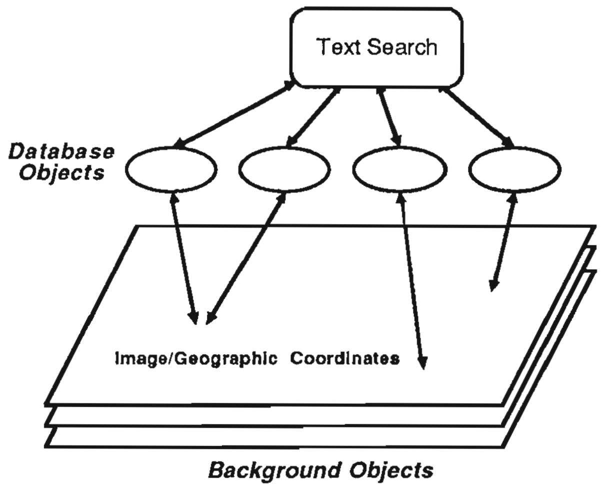

Fig. 1 HyperMap concept

3. SYSTEM DESCRIPTION

HyperMap provides tools for indexing, accessing, and displaying imagery and text data. These data are organized in two kinds of geographical objects as shown in Fig. 1:

- *Background objects* which can be thought of as coregistered map layers over a given geographical region
- *Database objects* that describe geographical features within the region

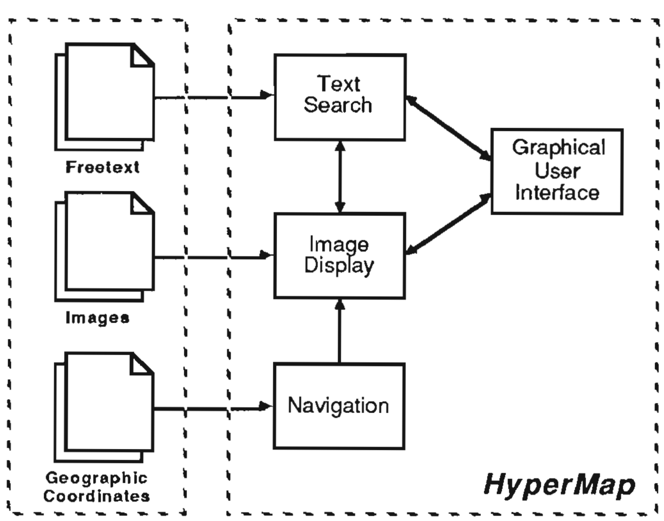

Fig. 2 System architecture

Each database object consists of an image and text file. Database objects are geo-referenced and so can be accessed spatially. Objects are also indexed by their textual component and so can be accessed by key words or index terms (attributes) that are either specified by the user or which appear in another object (as in hypertext systems). Query-by-example can also be used to find similar objects by matching their full text descriptions.

The system architecture is shown in Fig. 2. All data are maintained within the Macintosh file system. The file organization (Fig. 3) provides separate directories for background coordinate data and images, and for database images, text and coordinate files. Image sizes, screen layout, pathnames, and internal parameters for text processing are stored in a setup file. The file structure shown in Fig. 3 is replicated for each geographic region and database; "home" designates the directory where HyperMap is activated.

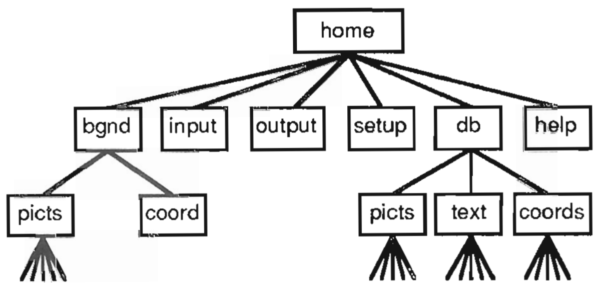

Fig. 3 File organization

3.1 NAVIGATION

The software is designed, at present, to handle one geographic region at a time. The current geographic region is defined by its corner latitudes and longitudes in a coordinate file ("home:bgnd:coord). Background images (bgnd:picts:**) are coregistered to this region and are assumed to be the same size (number of pixels). Database images (db:picts:**) are geo-referenced within the above region with the location of each database object stored in a separate coordinate file (db:coords:**). Corresponding text files are stored in db:text:**. The coordinates of any point in a background image are computed from the coordinate file by linear interpolation.

3.2 TEXT SEARCH

Full-text indexing provides an attractive alternative to the fixed record structure of relational database systems. Specific attributes can be described explicitly by key terms. More general descriptions can be captured implicitly in a short narrative. Full-text indexing allows database objects to be retrieved by key words, index terms, or free text queries. Texts are represented by signature vectors. Each word in the text is represented by a binary code. Words and their corresponding codes are maintained in a dictionary (the lexicon). Signature vectors are generated by a method known as overlap or surrogate coding[1,2] in which codes are "or-ed" together to form signature vectors. The similarity between two texts is given by the distance between their corresponding signature vectors. A query is converted into a signature vector which is compared with the other signature vectors in the database. Database objects are organized in a queue ordered by their match score where the most similar object is at the top of the queue. The user may step through the queue displaying the match score, text, and associated imagery with the background image display automatically updated to the location of the current database object.

3.3 IMAGE DISPLAY

For rapid display, images are stored in the Macintosh file system as PICT resources[3] which contain the image data in compressed form along with the corresponding color lookup table. Macintosh Toolbox routines are used to display PICT images in color windows. Each color window is an instance of a Macintosh Lisp object[4]. Multiple windows can be instantiated to show more than one background or database image at a time. Database windows can be roamed independently. Background windows are linked together via global variables so that they can be roamed together.

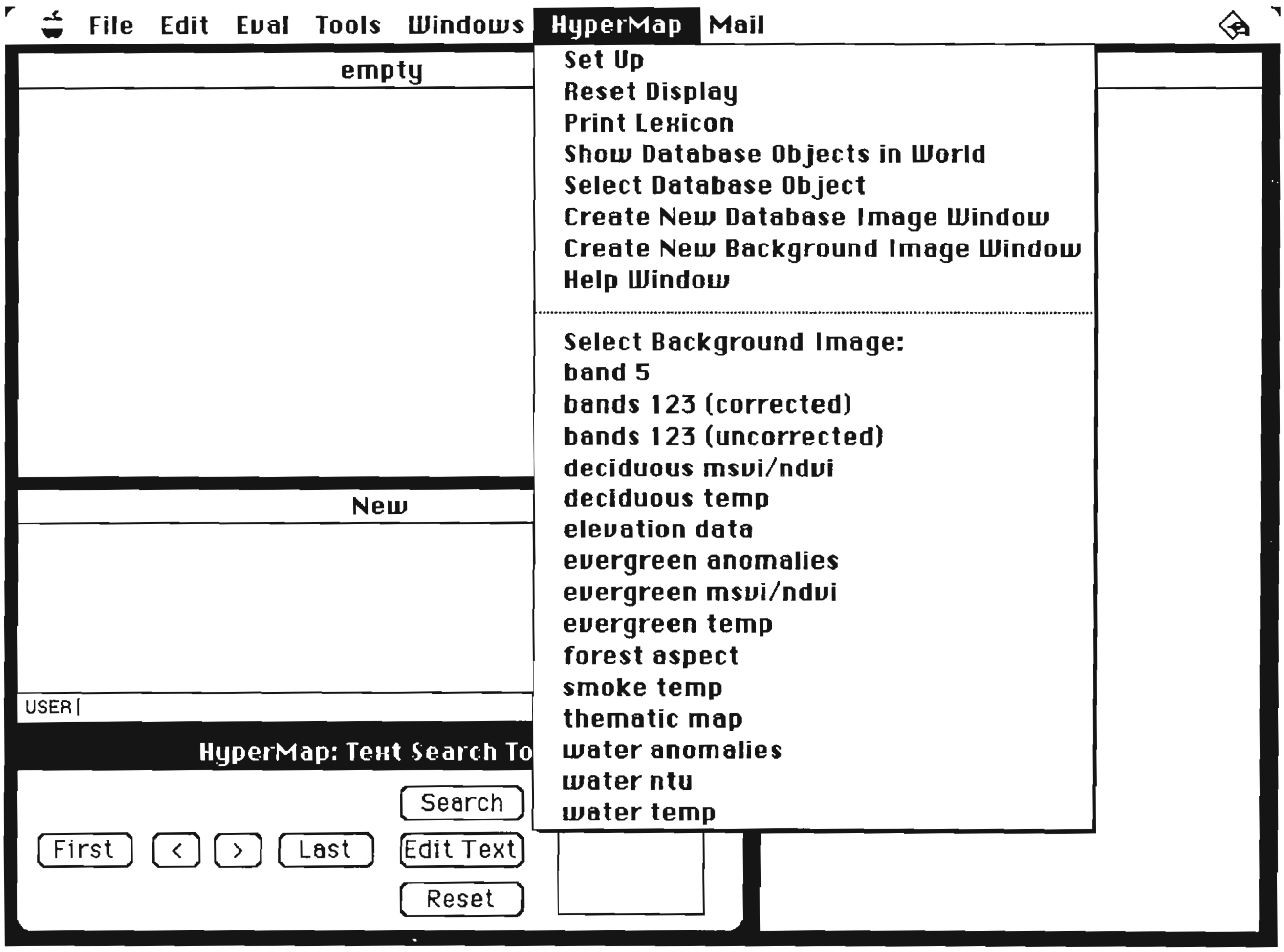

Fig. 4 Graphical user interface

3.4 GRAPHICAL USER INTERFACE

The GUI was implemented using the Allegro Interface Designer[4], a rapid prototyping tool for building user interfaces in the Lisp environment on the Macintosh. The following functions are available in the main pull-down menu (Fig. 4):

Set Up - loads all data files in the home directory, indexes the text files, creates background and database image windows, an editable text window, and the text search tool.
Reset Display - restores the initial screen configuration
Print Lexicon - prints all index terms in the text window in alphabetical order
Show Database Objects - Displays the position and name of all database objects that are visible in the current background image window
Select Database Object - Makes the object closest to the center of the window (denoted by cross-hairs) the current database object
Create New Database Image Window - Makes a copy of the current database image window
Create New Background Image Window - Makes a copy of the background image window
Help Window - Prints help information in the text window

The following control keys affect the currently active color window:

o image overview (scales image to fit within window)
p repaint screen
+ increase magnification by 2X
- decrease magnification by 2X
1 set magnification to 1
c go to center of image
l go to left side of image
r go to right side of image
t go to top of image
b go to bottom of image
w draw cross-hairs and print pixel coordinates (center of screen)
g draw cross-hairs and print geographic coordinates (center of screen)

The screen state is stored in global variables so that changes in one background window are reflected in the others.

Standard Macintosh control keys are defined for the text window that allow cut, paste, and other editing operations. The functionality of the text search tool which uses the text window is shown in Fig. 5.

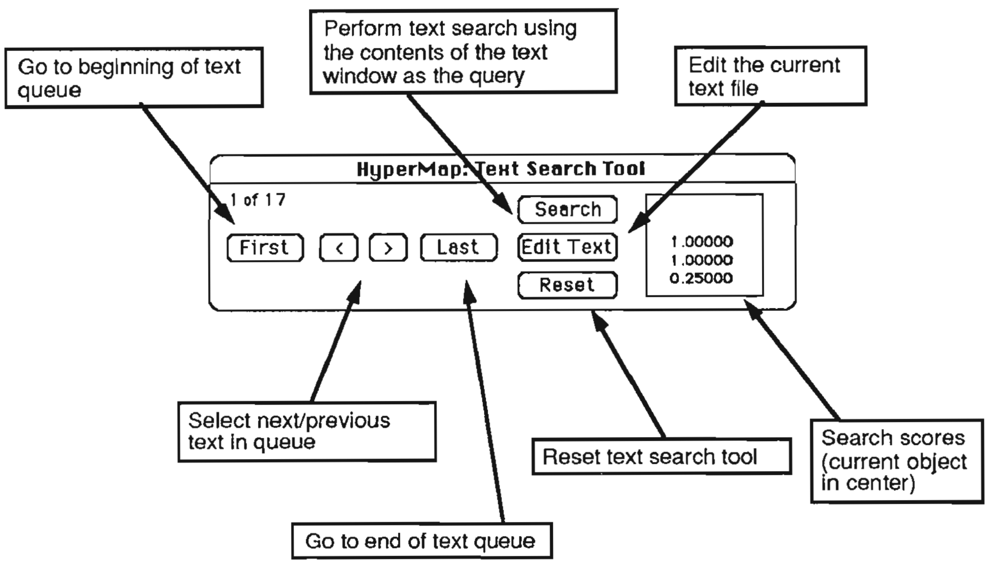

Fig. 5 Text search tool

4. CASE STUDY: ENVIRONMENTAL MONITORING

This section demonstrates the use of *HyperMap* in support of an environmental monitoring study. The objective of the study was to determine the utility of multispectral imagery in detecting environmental phenomena including stressed vegetation, water pollution, and atmospheric plumes. A variety of data were involved: multispectral satellite imagery (Landsat Thematic Mapper), image processing algorithm results, map data (elevation and land use), and ground truth (digitized photography and field reports). *HyperMap* was used to organize and analyze this information, in particular to retrieve ground truth over specific areas to verify image processing results, to view raw imagery, processing results, and maps together, and to assess the consistency of processing results from different images over the same area.

An area approximately 45 km by 24 km near Bitterfeld, in former East Germany, was selected for study because of its history of concentrated chemical manufacturing, strip mining and military training activities. Dense agricultural and forested areas surround the central industrial and residential districts of Bitterfeld. During a recent television report[5], this area was quoted as "the most polluted area in what may be the most polluted part of the world".

For this study, Landsat TM data acquired on September 4, 1986 were used. Land use information was derived by spectral classification. An elevation map was also acquired and coregistered to the imagery. Image processing algorithms were developed to detect vegetative stress, hydrologic and atmospheric pollution[6]. Multispectral imagery, image processing results, and map data were stored as background objects. Ground truth data consisting of field reports and photography were collected at 17 locations during a two day period in March 1992 to verify the image processing results. Ground truth photographs and text (derived from the field reports) were organized as database objects.

Fig. 6 shows the initial screen configuration provided at system start up. (Production costs precludes the use of color photographs in these proceedings.) On the right side of the screen, one of the background images derived from Landsat TM bands 1, 2, and 3 is shown. The geographic coordinates at the center of the window (denoted with cross-hairs) are indicated in the upper left hand corner of the window; ground truth collection locations are identified by an asterisk next to their respective names.

The three windows on the left side of the screen are used to access and display database objects. The upper left window shows the current database image. The middle window shows the text (caption) corresponding to the current database image. The same window is used for text retrieval. Here the result of a search for database objects containing the key terms "SourceGroundTruth" and "AtmosphericPlume" is shown. The bottom left window is the text search tool described earlier.

Fig. 7 illustrates how the system can be used to check image processing results, in this case, bodies of water with high turbidity. The background image window (right) shows the average turbidity computed from the Landsat imagery over bodies of water (the dark area indicates relatively turbid water). The spatial selection capability was used to retrieve the nearest ground truth site (left). The photograph shows a drainage ditch originating from a photo-chemical plant in the distance. Other similar images in the database were found by matching their corresponding full text descriptions (not shown).

Finally the ability to roam multiple background images is shown in Fig. 8 which shows three images arranged in an alternative screen configuration: moisture stress vegetation index (MSVI), Landsat band 5, and elevation data (low to high ranges from dark to light). The top image is used to assess vegetation stress which appears as dark regions. Our original hypothesis was that the stress was caused by air pollution emanating from Bitterfeld to the south. By viewing these three images together we concluded that the stress was probably due to mechanical damage (e.g., caused by vehicles driving through the forest) and not chemical damage from air pollution as originally hypothesized.

5. SUMMARY AND FUTURE WORK

A geographical information system for storing and retrieving imagery and text data was described. The system provides a flexible means for attributing geographical features using full-text indexing and retrieval techniques. It integrates content-based and spatial data access methods into a single environment. The system is easy to use and involves no programming on the part of the user. All data is stored in standard Macintosh PICT and ASCII file formats. The system represents a low cost means of storing and accessing imagery and text data for remote sensing and GIS applications on a standard color Macintosh with hard drive. Its use in an environmental monitoring project was described.

Currently we are considering the integration of video data which, like imagery, would be accessible spatially and by content. We are also considering migrating the system to other platforms.

6. REFERENCES

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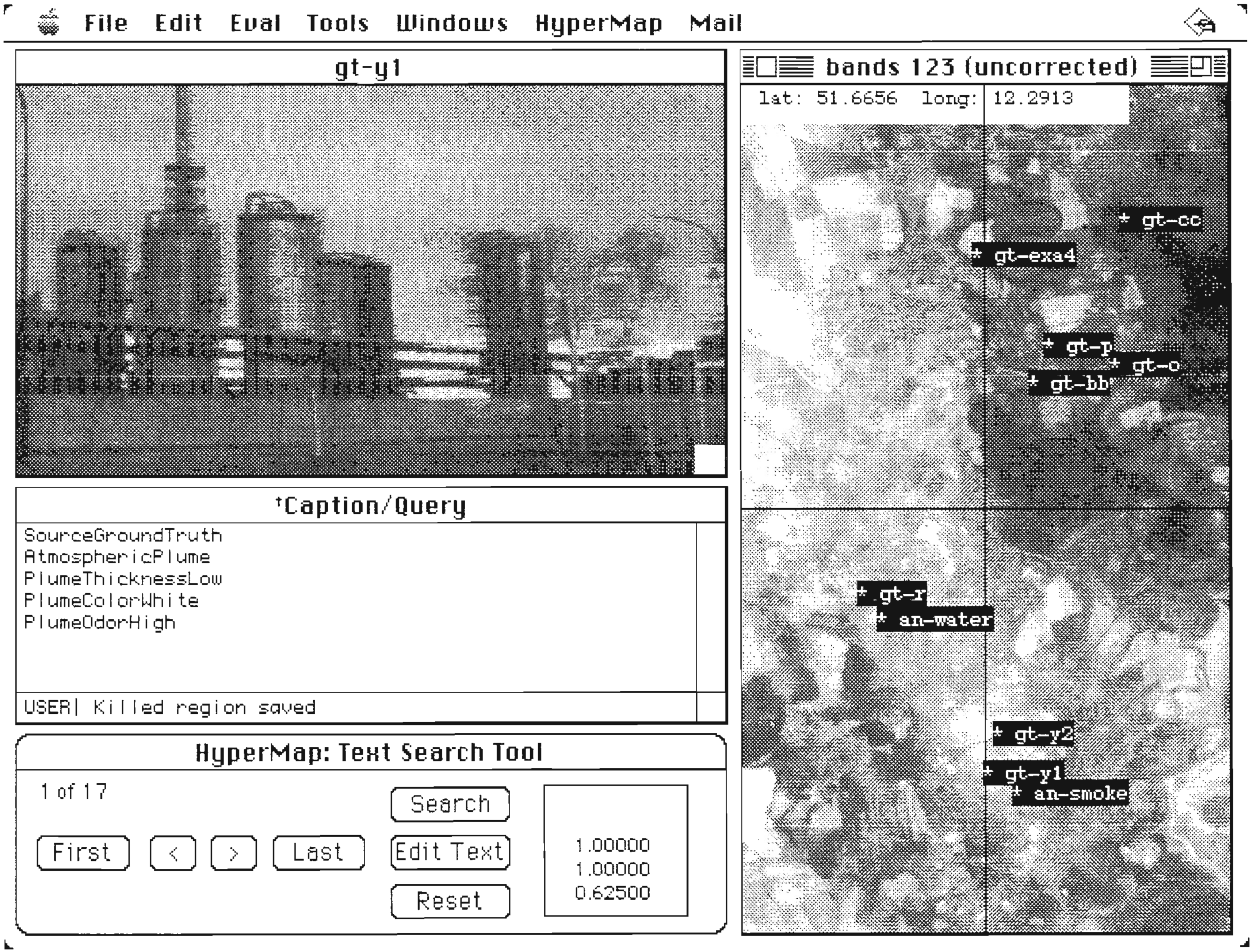

Fig. 6 Text search example with standard screen configuration (640x480 pixels)

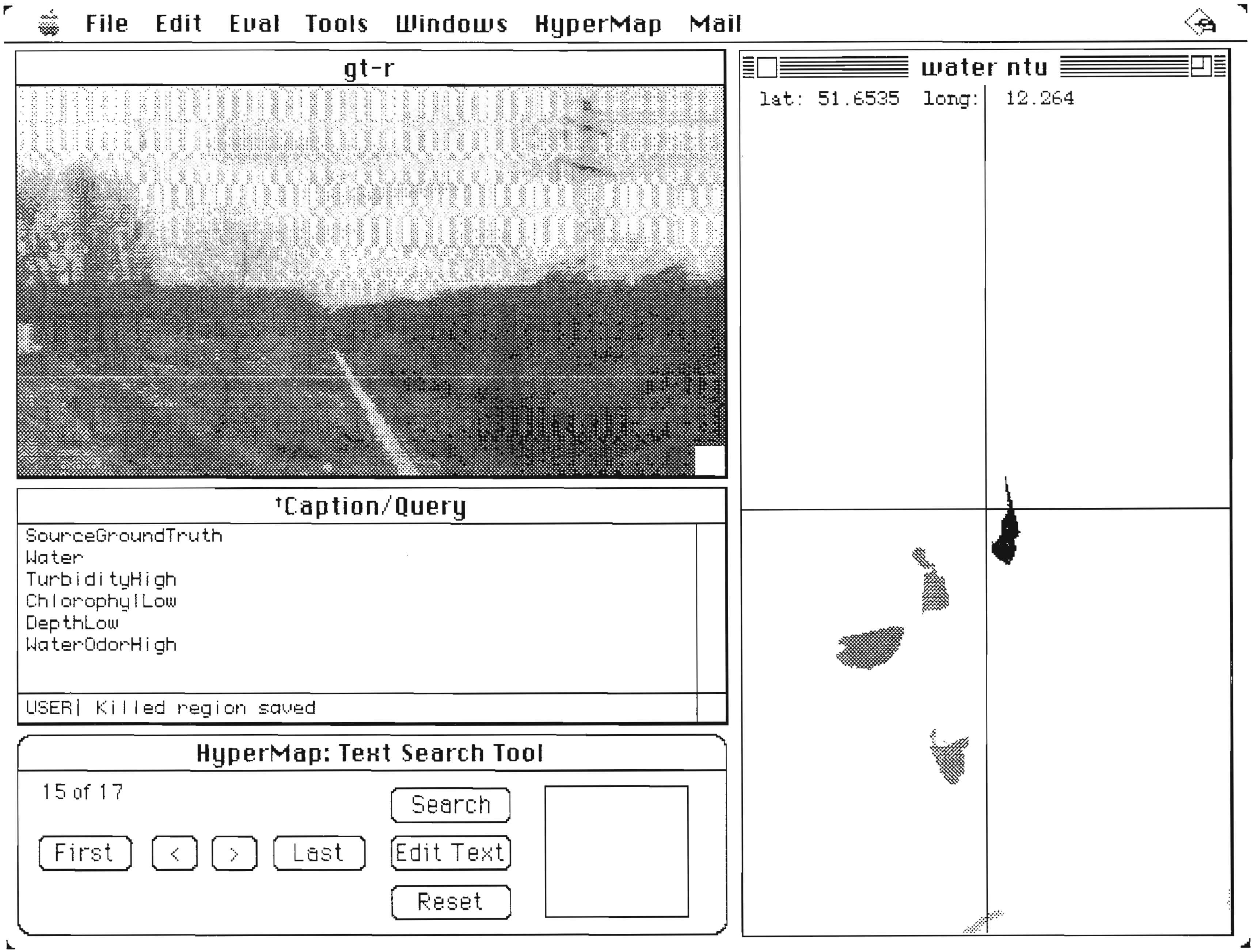

Fig. 7 Example of spatial retrieval of nearest object in database

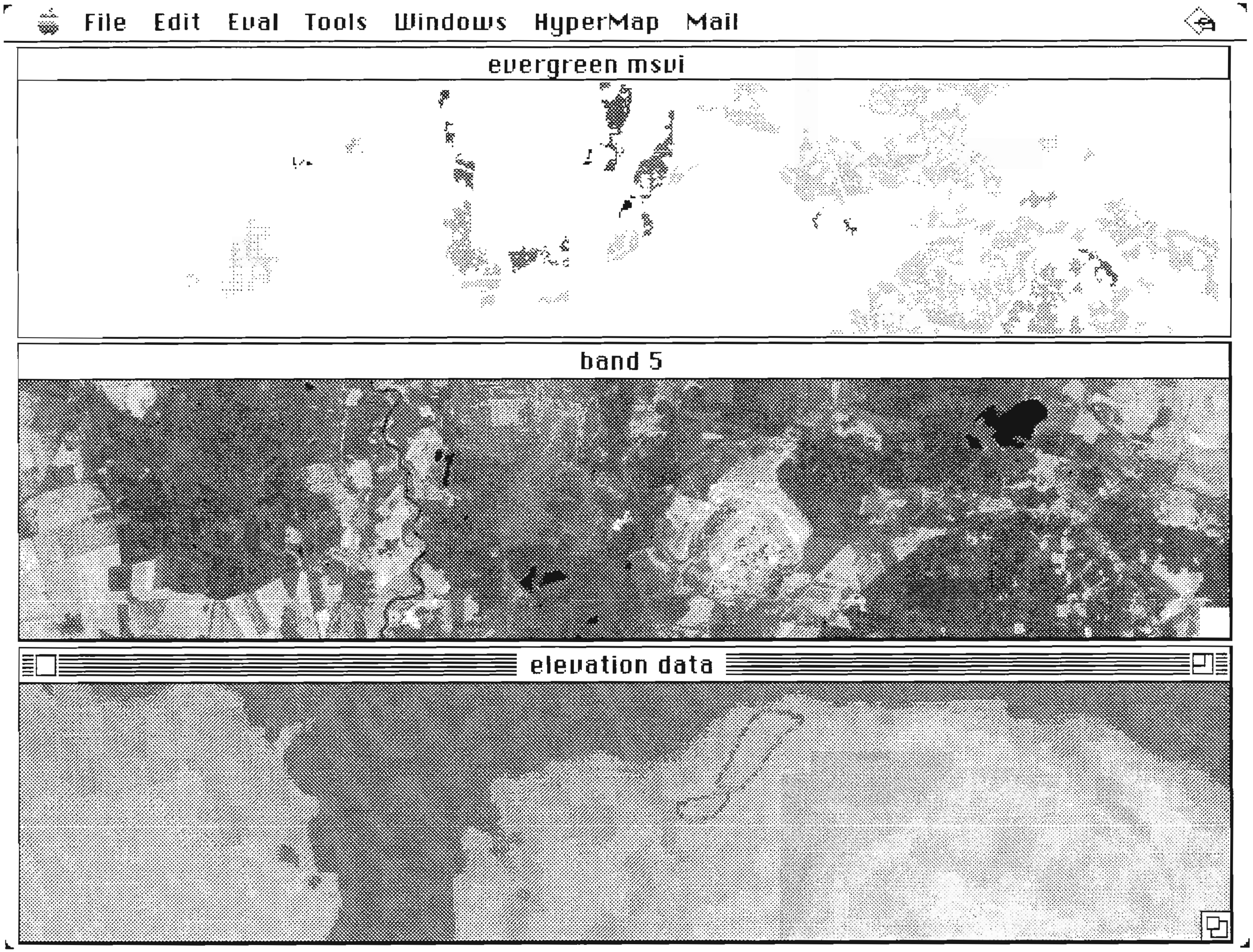

Fig. 8 Alternative screen configuration for roaming multiple linked background images