SEARCHING AND BROWSING INTERFACE FOR IMAGE DATABASES VIA INTERNET

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ABSTRACT:

With its easier availability, finer resolution and wider coverage of spectrum in recent years, remote sensing technology has emerged as a fast way for users in a variety of domains to acquire updated information. With such popularity, the needs nowadays are much greater than before, and we are even expecting an era that thousands of images may be produced per day. Although such a large number of images can certainly bring huge impacts to help us realizing the world, the accumulated data volume will sooner or later become a bottleneck for future image database. The idea of this research is to introduce human spatial concepts towards the selection of images from image databases. The core of suggested mechanism is the formalization of spatial relations based on humans' spatial cognition. With the aids of spatial browsing capability, images that covering interested area can be selected and later retrieved. This paper integrates knowledge for image selection and human spatial concept, which is just the beginning of this still-growing research topic.

1. BACKGROUND

With the technique improvement on easier availability, finer resolution and wider coverage of spectrum in recent years, remote sensing images have emerged as the most efficient way for users in a variety of domains to acquire updated information about the earth. Thousands of images from a variety of satellite platforms are produced and available via Internet nowadays. The fast development of Internet technology provides an extremely powerful environment for the sharing and distribution of remote sensing images (and of course the number of images may be overwhelming for users to handle). There are many famous image databases on Internet, such as USC-SIPI Image Database and NASA Image eXchange (NIX) etc. These databases all contain an enormous volume of images and the number of images keeps on growing everyday. Although such a large number of image databases provide a more complete coverage to the earth, it is more and more difficult for users to search images from such abundant data source. We proposed to introduce human spatial concepts into the image selection and browsing process in this paper, the ultimate goal is to reduce the difficulty of dealing with overwhelming amount of images.

Image database is an important and valuable data source to GIS. An image database is often a complex data search mechanism, such that users have to be well trained before they can operate the database management system effectively. Even images satisfying users' constraints are found, the selection of the most appropriate images may be another obstacle. An interface based on the analysis of users' spatial searching and browsing behaviour is certainly helpful to reduce the complexity of human-computer interaction and consequently improve the querying efficiency of remote sensing images via Internet. . For example, the request of images about the city of New York can be expressed as 'Select images that *cover* the city of New York.' Since spatial relationships, such as 'cover' in the above example, are frequently used in our daily lives, it would be easier for users to express such type of queries.

The basic concept of this paper is to incorporate knowledge of human spatial cognition into the interface for image selection and browsing. The core of the suggested mechanism is therefore based on the computer formalization of spatial relations that is applicable in the image searching and browsing process. For the current huge image archives, a typical situation is too many images may qualify users' constraints and it may require users a tremendous amount of time to visually inspect all the images before a conclusion can be reached. A 'smart' browsing interface based on the image selection knowledge from domain expertise can reduce the time required. For example, an image completely cover the interested area should be given a higher priority than those images only covering a part of the interested area. This suggests that the image mechanism should be capable of distinguishing the spatial relationships of 'entirely contain' from 'partly contain', though theoretically their formalizations are all based on the geometric intersection of two polygons (an image and an interested area). Therefore, users can still use 'cover' as their constraint, but the system should be able to act 'intelligently' to provide the queried result for further browse.

We are still in the early stage of this research and this paper can only present some preliminary results of the developed mechanism. Though far from practical use, we wish the discussion here can set up a foundation for our future research. Section 2 discusses the related analysis on spatial searching and browsing behaviours. Section 3 explains the basic mechanism of our system and section 4 demonstrates some test results. Finally section 5 conclude our major findings and explore possible developments in the future.

2. SPATIAL BROWSING BEHAVIOUR

For computers to 'understand' what humans want and act accordingly, it is clear further investigation on human knowledge modelling and spatial concept formalization is necessary. Human behaviour analysis and knowledge acquisition is therefore an urgent demand (Sestito & Dillon, 1994). The knowledge formalization and implementation in computers must include how data is represented and organized into considerations. Frank (1992) divided the creation of spatial data into three levels: spatial concept abstraction, spatial data modeling and spatial data structure. While humans may largely apply their spatial knowledge in the conceptual level (e.g., image schemata), the execution in computers is nonetheless often in the data structure level. It is therefore necessary to consider how to incorporate human spatial cognition into the computer system (Frank and Mark, 1992).

Humans frequently use spatial relationships to describe spatial phenomena in their daily lives (Egenhofer and Herrin, 1993). These spatial descriptions can be as simple as a simple spatial predicate, e.g., North of, or as complicated as the combination of several types of spatial relations, e.g., close + North of + disjoint. While humans usually express spatial relations in qualitative concept, most GIS systems are quantitative-based and fail to directly support the processing of qualitative spatial relations. An appropriate mapping between the two and mathematical formalization are necessary for any mechanism that tries to bring qualitative spatial relations into it user interface or query processing. The advantage is, however, if a system would allows users to express their queries in qualitative spatial relations, users can communicate with this system easier with spatial knowledge they already possess. Nevertheless, it is worthy to note even though humans can communicate with each other with qualitative spatial relations well, computer systems don't have such a spatial knowledge for interpretation and reasoning.

Frequently used spatial relation can be classified into three major categories: metric, direction and topology relations (Table 1).

Table 1.Spatial Relations types

Type	Metric	Direction	Topology
Description	Distance relation between A and B	Direction relation between A and B in specific direction system	Describing the related layout relation between A and B
Example	"It is Far between New York and Los Angle"	"Canada is North of United States"	Taiwan and Japan is disjoint
Graph	Far	North	Disjoint

While most DBMS deals with the 'search' behaviour of data satisfying users' constraint, 'browse' behaviour draws more and more attention with the rapidly increasing amount of data on the Internet. The Merriam Webster Dictionary define the word 'browse' as "to look over or through an aggregate of things casually especially in search of something of interest." Stephenson (1988) classifies the behaviour of human-computer interactions based two considerations:

- If users understand exactly what they need.
- If users know to acquire data from the system

Stephenson defined altogether six types of HCI behaviours: retrieving, searching, browsing, exploring, scanning and wandering. Figure 1 illustrates these six behaviors based on the above two considerations. Among them, only retrieving, searching and browsing are of major interests in this research. According to Stephenson's definition, these three behaviors are:

Retrieve: users know what data is and also know how to get the data through system interface.

Search: users know what data they want, but do not know exactly how to operate systems to get the data.

Browsing: users are not quite sure what they need and cannot specify an 'exact' constraint. The system must help users to narrow down the range of possible data.

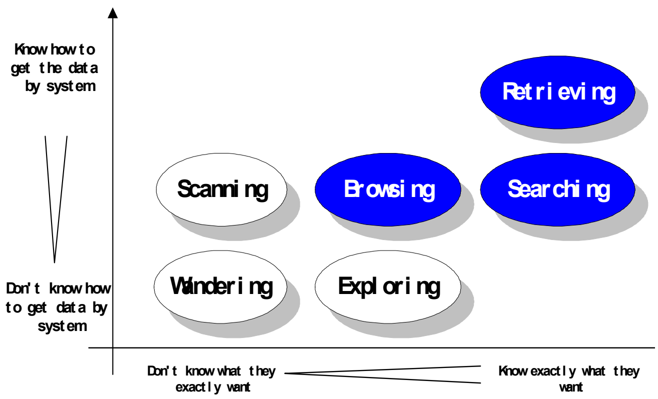

Figure 1. Interaction models between human and computer (Stephenson ,1988)

When users query an image database, the search of images satisfying users' constraints is completed by DBMS and retrieved for further visual inspection. The huge volume of image data will be a problem even for database administrators. Since the volume of qualifying images may be overwhelming, it becomes an important issue for systems to provide an effective searching and browsing mechanism to help users to precisely specify their requests and quickly browse images that may be of interests. The design of 'browsing environment' is based on the following two major principles:

a) Help users to identify required data step by step.
b) Provide a mechanism to sort qualified images based on image selection knowledge.

3. IMAGE DATABASE AND BROWSING MECHANISM

Every remote sensing image vendor has his own design on the images provided. The basic common characteristics of remote sensing images include:

(1) Specification

Every type of image has its own design on such characteristics as format, sensors, spectral bands, satellite orbits, etc. The specification of images may influence if this type of images is chosen. For example, when requesting an image providing an overview of Taiwan, it is no necessary to search aerial photos because of their relatively small size when compared to the area of Taiwan.

(2) Spatial coverage
Every image has its own spatial coverage on the ground. Any image search must be based on the 'geometric intersection' test between the area of interests and the spatial coverage of images.

(3) Time
Every image is acquired at a specific time. Many image queries include temporal constraints, such as 'find images that is taken after the 921 earthquake.'

Note what we really need is the content of images, the above description merely provide us a way to select images we need (e.g., images cover the city of New York). Unfortunately, users can only determine if an image satisfying his or her needs only after they have a chance to visually inspect the image. Besides, the information is hidden in the images, users must have a capability to correctly interpret images before they can determine if the image can be used. More help from systems to aid users' interpretation is certainly preferred, for example, superimpose the boundary of the area of interests on the image.

Figure 2 shows the system framework of our proposed system. Four important concepts will be described in the following:

- Image database is a physical storage device for storing raw images (and possibly their re-sampled, low-resolution images). Users can retrieve re-sampled or full-sized images at their will for further visual inspection.
- The image metadata database provides all the necessary information about image to the searching and browsing mechanism, so that the qualifying images can be reduced to a reasonable number before visual inspection begins.
- A spatial searching and browsing mechanism receive constraints created in spatial browser, translate the constraints to appropriate spatial predicate based on spatial knowledge, request metadata based on knowledge about image, then determine the images qualified.
- The user interface for browsing mechanism allows users to specify their spatial constraints based on their spatial concepts. The queried result is passed to the interface for users to make further choice.

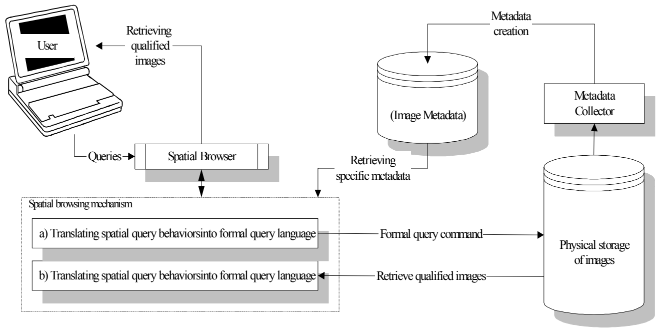

Figure 2. Proposed system structure

3.1 Image Metadata

A general definition of metadata is "data about data". It is the description information about existing data used to help users to have more understanding toward the data before they really use it. No matter it is a long statement or a list of elements, an ideal metadata must be able to clearly explain the basic nature of the data it describes. Table 2 lists the suggested image metadata elements in our system:

Type		Discussions
Spatial information		Spatial metadata records the ground coverage of the respective image. This information can be used to calculate spatial relations□metric, direction and topology relations □ between interested region and image. Though the coverage specification may vary from one type of image to another, as long as the coverage is a rectangle, it can be represented by the coordinates of its four corners.
Temporal information		Temporal metadata records the time an image is acquired. It therefore represents a snapshot of the phenomena in real world. It is directly available from satellite on-board data in a yy/mm/dd/hh/mm/ss format. Many DBMS and GIS software support DATE or TIME data type to store temporal metadata. Temporal data can be used for queries like 'find images acquired in day time.'
Reference information Some image native attributes may be the constraints for image selection. For Example,	**Spatial resolution**	This element refers to the correponding ground size of an image pixels. For example, the resolution of LANDSAT images ranges from 30m to 120m. Since this element provides description how 'detailed' the image describe the real world phenomena, it is an important judgment factor for image browsing.

we will adopt IR images for vegetation detection	**Spectrum resolution**	The spectrum of images has a tremendous impact on whether the image can be used in a particular application. For example, images of microwave length are often used in water detection application.
	Sensor type	Related sensor name, satellite height, orbit parameters and other sensor information.
	Cloud Coverage	Cloud coverage can be used as image selection knowledge for visual verification sequence. Images with higher cloud coverage are given a lower priority.

Table 2. Adopted image metadata items and description

For better management and query efficiency, metadata for all the images are collected and stored in an independent database. We can therefore narrow down the possible images from the huge image archive by only using metadata database, and later retrieve only the images that meet users' demands.

3.2 Spatial Browsing Mechanism

There are several important missions for spatial browsing interface, including

- Retrieving necessary data items from image metadata database and introducing a friendly and user-oriented intuitive user interface to users.
- Processing spatial queries and constraints
- Executing queries
- Retrieving qualified images and sorting them based on image selection knowledge

Users can specify query constraints and browse the retrieved images in the designed interface. We summarize some necessary characteristics for ideal spatial browsing interface:

- ◆ Auxiliary data is necessary. For example, an index map helps users to have a better understanding about the spatial relationship between images and the selected regions.
- ◆ Thematic data, such as maps with annotations, help users to define the extent of interests.
- ◆ Ideal and intuitive interface for spatial constraints creation is necessary. Users can specify spatial constraints by point, line or regions, and further integrate them with the use of spatial relations.
- ◆ System must be able to process users' spatial relation queries received and retrieve necessary metadata □e.g. image coverage extent□. The display of qualifying images must be based on advanced cartographic knowledge.
- ◆ In the situation where more than one image qualifying given constraints, the result must be appropriately sorted based on developed image selection knowledge before presenting to users.

3.3 Spatial relation formalization

To provide users an intuitive interface for querying images, spatial relation formalization is necessary. No matter what type of spatial constraint is, the most important requirement regarding image queries is 'the qualified image must cover the area of interests', represented by:

QUALIFIED_IMAGE_TEST(candidate image) = **TRUE**

IF COVER(candidate images , region of interest) = **TRUE**

In other words, there are two main factors to evaluate when considering if an image is spatially qualified.

- The spatial coverage of candidate images and area of interests
- The definition for spatial relation "COVER"

Candidate image--The spatial coverage of the candidate images can be directly retrieved from metadata database. If further constraint like resolution or even application is specified, some types of images may be ignored.
Area of interests—There are two approaches to create area of interests, either by directly creating an area of interests or by using the combination of reference objects and spatial relations. The first approach is similar to the basic selection tool most GIS software provides (point, line, polygons). The second approach would require the interpretation of the geometric meaning of the selected spatial relationships (e.g. the *east part* of the United States). Reference object can be point, line or region type.
COVER relation—This relation can be defined with the geometric intersection algorithm. However, the developed algorithm must be applicable to all of the possible situation, i.e., point-polygon, line-polygon and polygon-polygon. Table 3 summarizes the types of spatial relation involved in browsing behaviours.

Spatial relation type	Example
Metric relation	Expressing the "far" or "near" concept. Metric relation is always used simultaneously with reference object in our system.
Direction relation	Direction relation is defined on the basis of reference object as well. Area of interests can be created by the combination of reference object and specific spatial relation. (e.g. East of the city of New York). The definition of direction relation changes with the dimensionality of reference objects.
Topology relation	The frequently used topology relation in browsing behavior is **COVER**

Table 3. Spatial relations for image database browsing

4. IMPLEMENTATION

This section demonstrates some of our preliminary results regarding to the image searching and browsing via Internet. Since we are in the early stage of the research, some of the developed spatial predicates are still incomplete and most of the data is only simulated. We separate the system development into two parts, the first part relates to Internet technology, while the second part deals with the development of spatial predicates. For Internet part, ESRI ArcIMS was chosen as the test platform for the image database. ArcIMS is the first server-side solution for Internet GIS development, further system development and customisation is possible with the support of JAVA language. A server-side solution, such as the 3-tier structure of ArcIMS, has the advantage of protecting data from illegal downloads. To be able to provide higher customisation ability, the Internet spatial query interface is developed with JSP and Servlet, which are client independent so that users can browse without download plug-ins. It saves Microsoft SQL Server 2000 is chosen as the database platform to process alphanumeric data and we also introduce robust JDBC interface module for Chinese characters displaying and querying. At the moment, the specific implementations in this paper include two separate parts, and these two parts will be integrated in the future research:

- Implementation of Internet GIS interfaces
- Spatial browsing mechanism kernel test

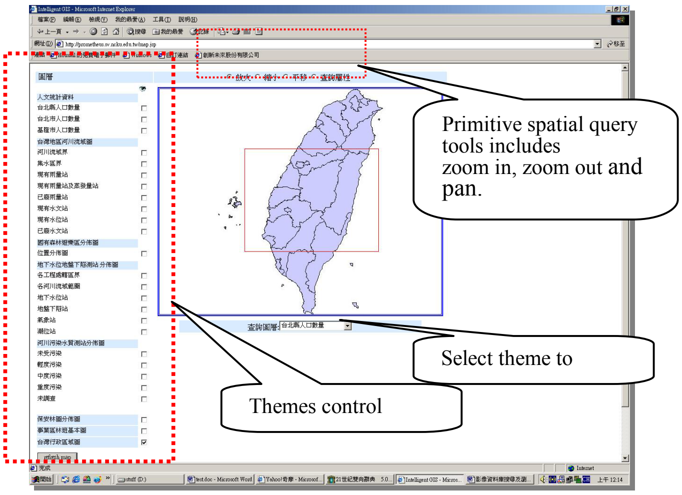

Figure 3. Internet client interface

In order to implement proposed system structure, there should be a client connector for users to login system with common Internet www browsers. We adopt the JSP + JavaScript solution to have better query efficiency and a more completed expansion capability on user client interface. A primitive test system interface is shown in Figure 3. It supplies a set of primitive spatial browsing tools (e.g. zoom, pan) to help users to specify region of interests. We implement these primitive spatial interaction tools by JavaScript. For pure JSP framework can do little things about client user interface modification.

For faster calculations and better security on system kernel source code, we plan to implement the second part with CGI (Common Gateway Interface). This part is still under development with JAVA and shall be integrated with the first part soon. In order to test the spatial relation module, we create an image database with 5000 records of simulated image metadata. Both the time and spatial coverage of images are simulated randomly. Figure 4 illustrates the distribution of simulated images by using color brightness to represent time difference. The system is temporarily developed and tested in ArcView environment.

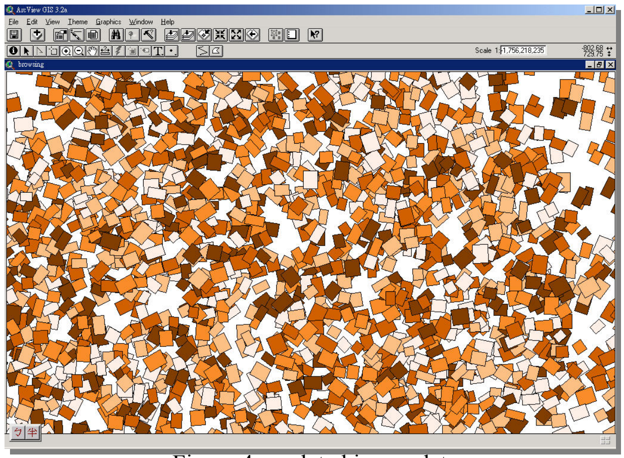

Figure 4 emulated image data

Figure 5 shows a query regarding the spatial predicate 'along', which is often used for linear objects or the boundary of polygons, e.g., images along a highway. Theoretically this can be done with a geometric intersection test, but it is certainly not equal to simply an 'intersection' test. In the browsing interface, the linear constraint will be automatically divided into two categories of line segments, one category covered by images and one category not. Users can therefore have a clear understanding about how images can be used in their applications.

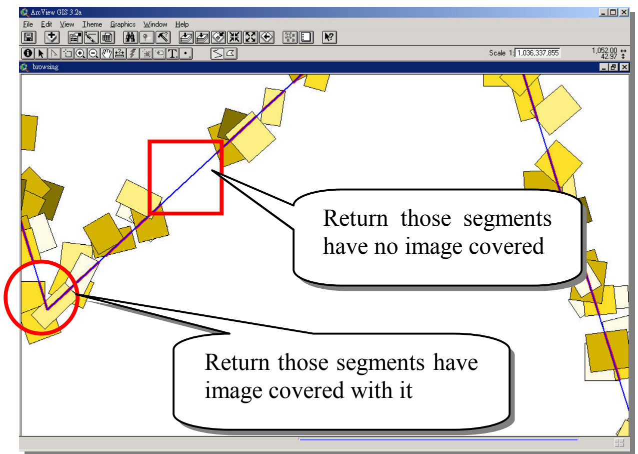

Figure 5. Line algorithm test

Figure 6 shows a query regarding to the spatial predicate 'cover', which can be used for point, line, and polygons. This is again based on the geometric intersection tests. Note in this case the area of interests is much larger than the size of any image, so no image can entirely cover the selected area. Under such circumstance, some of the areas may be covered by a number of images, while some areas may not be covered at all. Like the above case, the selected area must be divided into two categories for users further browse.

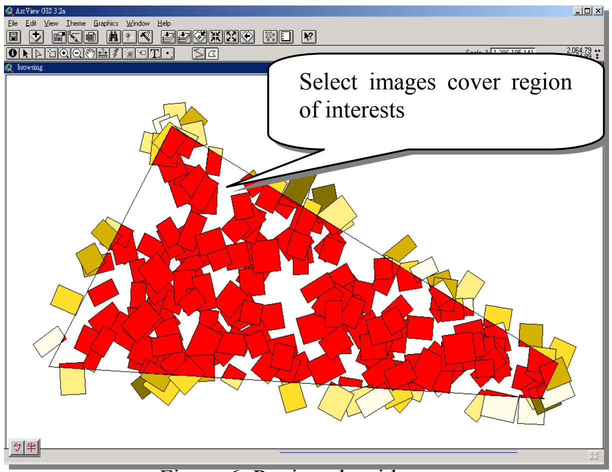

Figure 6. Region algorithm test

The next step is to integrate these two components together and it is still under development. One problem to the integration is to improve the efficiency of the JAVA spatial relation module. We will discuss the integration steps in future papers.

5. CONCLUSIONS

Remote sensing image has become the most important and efficient source for the collection and update of GIS data. With such a huge volume of images produced everyday, an efficient image searching and browsing mechanism and a friendly interface is necessary. The Internet image-browsing framework proposed in this paper is an attempt to incorporate human spatial and domain knowledge towards the image selection via Internet. By specifying constraints with spatial relationships, users can interact with image database easily and intuitively with the help from smart browsing mechanism. There are some important issues for smart browser implementation in the future, including efficiency improvement and distributed structure.

This paper is the first part of this research. We hope to successfully integrate corresponding components described in this paper together. A JAVA spatial relation kernel is under development. It may increase the portability of proposed spatial mechanism. Distributed structure is another import issue for this research for future image databases utilization.

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