INTELLIGENT IMAGERY SYSTEM: A PROPOSED APPROACH

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Abstract

Integrating remote sensing raster imagery with corresponding existing vector data is an essential requirement for efficiently handling and monitoring the surface of the earth. Two main approaches exist for integrating the two data types. One well-researched approach is to process the remote sensing imagery within an Image Processing System (IPS), and the information extracted might be digitized and input to a GIS. GIS data also might be used to better extract information from remote sensing imagery. Another approach is to use the remote sensing imagery as a backdrop for the vector map for the purpose of map updating and/or better visualization.

A new "Intelligent Imagery" system proposed in this paper suggests a different approach to integrating the richness of imagery with the attribute knowledge embedded in previously-interpreted vector data. While other approaches stack vector data layers on top of the imagery, this approach keeps the corresponding vector data hidden and utilize them internally until results need to be displayed. This approach is based on using remote sensing imagery, supported by *hidden* vector data and the associated attributes stored in a GIS, as an interactive medium with the real world. Through this medium, the user can issue a cursor specific query, display a Data Base Management System (DBMS) query results directly on the image, issue a query based on a delineated polygon of any shape in the image, and perform any spatial analysis task based on the complete, current, and reliable view of the remote sensing imagery. This method will eliminate the need for simultaneous display of vector and raster data or for vector/raster overlays/conversion that might lead to a loss of accuracy, confusion or hide important spatial patterns that could affect the final decision criteria. This paper will present the components of this new research, and outline its proposed benefits and limitations

1. INTRODUCTION

Aiborne or spaceborne remote sensing imagery serves as an effective, fast, current, and reliable tool for collecting spatial data. During this decade, many organizations all over the world are dedicating a great deal of their efforts to collecting, storing, and distributing their products of remote sensing imagery in an efficient manner. For example, Service New Brunswick “SNB” is in the process of constructing a large orthophotomap database covering the whole cost of New Brunswick at a scale of 1:10,000, and aim to extend this effort to eventually cover the whole province. The United States Geological Survey “USGS” is creating the so-called “National Geospatial Data Clearinghouse” (USGS, 1998). The clearinghouse is providing a tool to find information about geospatial or spatially referenced data available from USGS. One division of the clearinghouse is for National Mapping and Remotely Sensed Data (USGS, 1998). In that division you have a variety of choices between Satellite imagery at different resolutions and spectral bands, and digital orthophotos at scale of 1:12,000. Space Imaging company announced the release of the first 1 meter resolution satellite image from IKONOS satellite (Space Imaging, 1999). The current Canadian and European space agencies will continue launching radar sensors which can collect night time imagery. More than 30 earth observation and monitoring satellites with a variety of different resolutions and spectral bands are lining up to fly by the start of this (Stony and Hughes, 1998). With the above mentioned very few examples we can feel that we are really heading towards the so called “ Decade of Imagery” (Stefanidis, 1997) .

On the other side of the spatial information highway, rather than the raster remote sensing imagery, a huge amount of digital vector map data is available and updated at a regular base. These data are collected by digitizing existing hardcopy maps or are collected directly, in digital form, such as GPS map files or CAD files. For a long time, governments and private organizations have been dealing with collecting map data in digital forms. For example, SNB provides digital topographic maps at a scale of 1:10,000 covering the whole province. USGS has a collection of 70,000 topographic map sheets at different scales. One can order a digital map from the nearest "*map dealer*" distributed across the United States. Topographic maps and digital spatial data for Australia at (1:250,000), (1:100,000) & (1:50,000) are available through the Australian Surveying & Land Information Group (http://www.auslig.gov.au/). These examples are just few components in the so-called "Spatial Data Infrastructure".

Integrating remote sensing raster imagery with the already existing vector data is an essential tool for handling and monitoring our earth surface efficiently. With the advances in technology, we now can handle remote sensing imagery and vector data within an Integrated GIS "IGIS" environment in a certain manner and with certain limitations. Two main approaches exist for integrating the two data types. One approach is to process the remote sensing imagery within an Image Processing System "IPS" and the information extracted might be digitized and input to a GIS. GIS data also might be used to better extract information from remote sensing imagery. Another approach is using the remote sensing imagery as a backdrop for the vector map for a better and current view and analysis to the earth phenomena and for map updating.

In the proposed system, a new approach of using raster remote sensing imagery with vector database for better visualization, more flexible handling, and efficient analysis of spatial phenomena will be examined. The proposed approach is based on the idea of using remote sensing imagery, supported by hidden vector database and the associated attributes stored in a GIS, as an interactive medium with the real world through which we can issue a cursor specific query, display a Data Base Management System (DBMS) query results directly on the image, and issue a query based on a delineated polygon of any shape in the image. This method will eliminate the need for simultaneous display or for vector/raster overlays which might lead to confusion or hide important spatial patterns thus affecting the final decision criteria. In the following section, the frame work of integrating remote sensing imagery and GIS will be presented

2. REMOTE SENSING & GIS INTEGRATION

Although the integration of remote sensing and GIS has been widely covered in the literature and various techniques have been used in a variety of applications and disciplines, three main levels of integration between remote sensing and GIS had been identified by Ehlers et al [1989]. The characteristics of these levels may be summarized as shown in the next section.

2.1 Levels of Integration

2.1.1 Level I

This level is called " Separate but Equal" which indicates separate image processing and GIS system. In this system the user would be able to simultaneously display vector data and remote sensing imagery and to move the image analysis results into the GIS, digitize a classified image for example, and vice versa, use GIS data to georeference the imagery. This level is therefore mainly based upon exchanging data between systems. This level is considered to be a very early level of integration. With the advances in computer technology, this level is now disappearing and replaced by an advanced level of integration.

2.1.2 Level II

This level was named "Seamless Integration" in which raster-vector processing is allowed. In that system, GIS and image analysis systems are stored in the same computer and simultaneous access to the functions of both systems is allowed through a common interface while still having separate systems and the need to exchange data between the two systems. Although the problems of format conversion and raster/vector overlays have been reported for the usage of that level, it temporarily helps in performing the integration task.

2.1.3 Level III

This system is called “Total Integration” in which we have one system that allows the user to process remote sensing data and vector data simultaneously, to make use of full GIS and image analysis functionality simultaneously with no need for data conversion between systems. This system was identified 10 years ago but even with all the present technology push, image processing and GIS software vendors are still trying to merge in order to approach the functionality of the total integration.

Most commercial GIS or image processing software packages currently support only the first two levels. Achieving level III integration or total integration will require several steps. In total integration we can use a vector database, remote sensing imagery and/or both for spatial analysis. These data sources should be seamlessly linked together and based on the situation, either vector maps or raster remote sensing imagery can be used to query the real world and perform any kind of spatial analysis.

2.2 Use of GIS and Remote Sensing Data

In general, Wilkinson [1996] identified 3 major categories of GIS/Remote Sensing integration. Those categories may be summarized as follows:

1- Category A: Remote sensing used to gather data sets for GIS.

2- Category B: GIS data used to aid image processing, image interpretation and feature extraction from remote sensing imagery.

3- Category C: Remote sensing and GIS data used together in environmental modeling and analysis.

The approach of using remote sensing imagery supported by the existing GIS vector data as a tool or reference layer in querying the real world belongs to the third of the above mentioned categories.

2.3 Roles of Remote Sensing Imagery Within an “IGIS”

Remote sensing imagery plays three main roles in an integrated GIS (Derenyi and Fraser, 1996). These roles can be summarized as follows:

2.3.1 Passive Role

In this case the image is registered and geo-referenced to the ground coordinate system with the aid of several well-defined features or points in the image as well as on the ground. Then, a classification algorithm is applied to the remotely sensed imagery in order to produce thematic maps. The results could be digitized and entered to the GIS as a vector layer. For another typical application, the image is attached to the multi-layered GIS system and serves as a backdrop to the existing vector layers in the GIS for the purpose of either updating these GIS layers or else querying these vector layers for better visual analysis using the image. The superimposition of vector layers over an image covering the area under consideration gives the user better visualization and understanding to the situation.

2.3.2 Stand-alone Role

Nowadays, many software tools exist that allow the user to create digital orthophotos from scanned imagery. The popularity of creating and using orthoimages as base maps is rapidly increasing among many users and organizations. For example, Service New Brunswick (SNB) is now establishing a large database of orthophoto maps covering the whole coast line of the province and is planning to eventually cover the whole province.

2.3.3 Active Role

In that stage, remotely sensed images are directly involved in spatial analysis and data queries, and as a result, provide a more complete, current and accurate view of the real world for better decision making. The first author’s research mainly

deals with the active use of remote sensing imagery. The schematic diagram in Figure 1 gives an overview of the framework of remote sensing and GIS integration and where this research fits in the total picture.
Based on the previous three sections, a remote sensing and GIS integration framework can be presented as shown in Figure 1. In Figure 1, there are three major ways in utilizing remote sensing and GIS vector data. In the first, category (A) as mentioned earlier, remote sensing imagery is used as a data source for GIS and then the GIS vector data is used alone as a tool for spatial analysis. At that stage, the image is playing a passive role. For example, Boumgartner and Apfl [1994] classified satellite imagery and transferred the results by digitization into a GIS to create snow maps. Chuvieco and Congalton [1989] utilized the digitally processed Thematic Mapper data as a layer in their GIS to map the forest fire hazard at the Mediterranean coast of Spain. Jakubavskas et al. [1990] used Landsat MSS images taken at two different dates as a source to create vegetation maps and then a GIS system was used to examine the effects of fire in the vegetation changes in a Michigan pine forest. A good review on the use of remotely sensed data as an information source for GIS can be found in (Trotter, 1991).

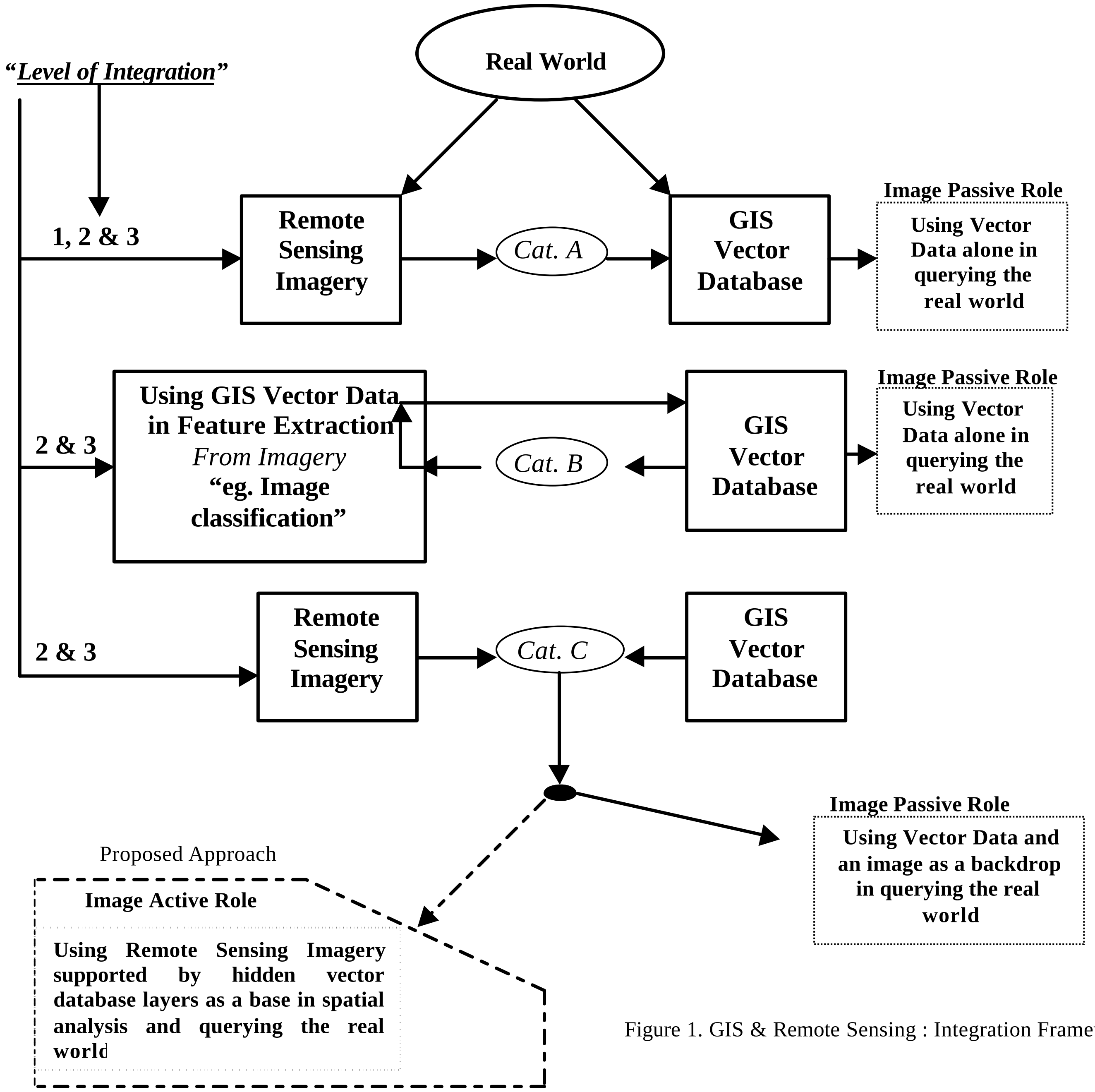

Figure 1. GIS & Remote Sensing : Integration Framework

In the second, category (B) as mentioned earlier, GIS data is used as an aid for extracting accurate information from the image such as extracting forest polygons through image classification using GIS ancillary data. This information is then digitized and entered into the vector GIS for further analysis. Also in this case, the image is playing a passive role. Numerous examples exist that use GIS data as a knowledge base for image classification. For example, Molenaar and Janssen [1990] used GIS data in a knowledge-based system to improve the image segmentation and classification for the Polder areas in the Netherlands. Van Cleynenbreugel et al. [1990] utilized GIS data to automatically extract road structures from remote sensing imagery. Kontoes et al. [1992] developed a method and a "reasoning program" to post-process the classified image data using GIS data. Jenssen et al. [1990] incorporated GIS topographic data to identify polygons in the image and to identify the pixels that belong to each polygon in a per-polygon image classification. An increase in the classification accuracy by 12~20% over the conventional per-pixel classification was reported.

In category C as mentioned earlier, GIS and remote sensing imagery can be used together in spatial analysis such as using the image as a backdrop for the vector data for better visualization or map updating. Again in this case the image is playing a passive role. For example, Derenyi and Turker [1995] developed a system of integration by which they could integrate GIS vector data and Satellite imagery to perform a polygon-based image analysis and classification. In order to examine the main cause of oak mortality in rural and urban environments throughout central Texas, Ware [1990] used interpreted aerial photos overlaid with urban barriers such as streets, water lines and houses and monitors the effect of these barriers on the oak disease. Ambrosia et al. [1998] used GIS ancillary information overlaid with raster airborne imagery and assisted by communication means in allocating resources against fire in a near-real-time process to detect fires at early stages and to minimize the damage. Gamba and Casciati [1998] utilized GIS and image understanding techniques in the RAATT (RApid Damage Assessment Telematic Tool) project, funded by the European Commission, to early and near-real-time assessment of earthquake damage in the Umbria region (Central Italy). Koch and El-baz [1998] used Landsat TM imagery to create a surface change map and a classification map. Then, these maps with Spot pan. image, topographic maps, geomorphic maps, and surface sediment maps of Kuwait were integrated in a GIS to asses the effect of Gulf war on the geomorphic features of Kuwait.

As shown in the previous examples, in all three categories, the main roles of images are either as a source of data or as a backdrop to the vector data i.e. the image is in a "passive state". The proposed approach is falling into category (C) but using the image as a reference layer supported by hidden GIS vector data layers to perform spatial analysis. In the proposed approach the image is playing an "active role" in the integration between remote sensing and GIS.

3. PROPOSED SYSTEM

Figure 2 illustrates the workflow of the proposed system. Having a georeferenced imagery displayed on the screen, and the vector database layers covering the same area accessible to the system, the user can then decide on the data layers that will be involved in the spatial analysis and activate them. Then, he/she has three kinds of functions. First, the user can point to a feature on the image to retrieve information about that feature. In that query, the system will take the pointed pixel coordinates, convert them to ground coordinates, search the database with this set of coordinates and retrieve all available information based on these coordinates. Due to errors in the registration and georeferencing procedure, the pixel coordinates might not be found in the vector database. In this case a search circle with a predefined radius should be constructed and the system will try to find the feature/pixel attributes within this circle. If nothing is found, so that particular feature does not seem to exist, and the vector database needs to be updated.

In the second function, the user queries the database itself with a query statement. The system then identifies the features related to that query, defines their occupation areas, identifies the screen pixels that belong to these features, and highlight them.

The third type of analysis is based on delineating a polygon of any shape on the image, build a query statement inside this polygon, then display or retrieve the desired features/information related to that query.

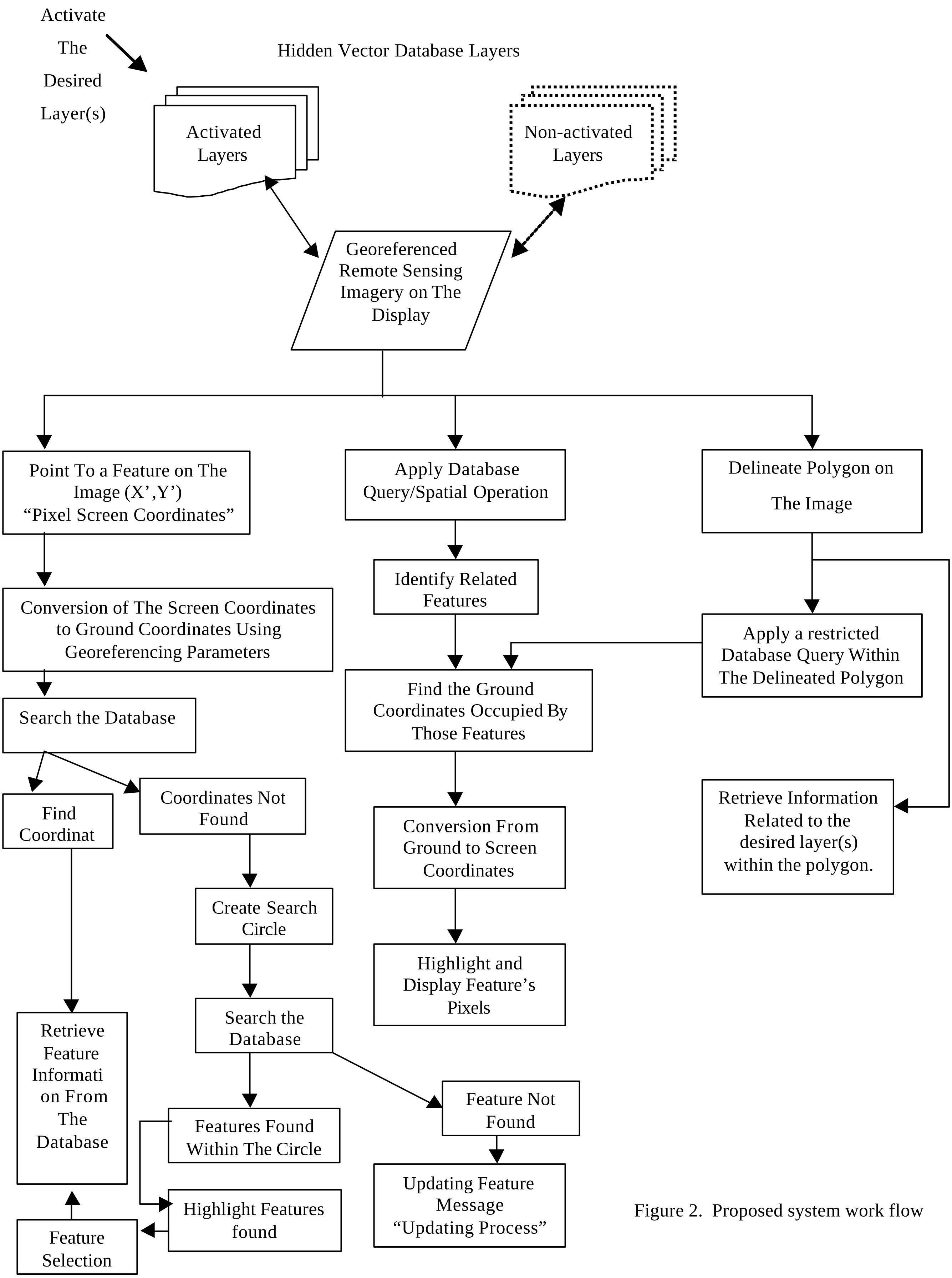

Figure 2. Proposed system work flow

In order to select the proper tools to be integrated to construct the proposed system components, a requirement analysis has been conducted which reflected the tools and the main components necessary for the system to perform its pre-defined functions. Further, a thorough investigation inside the GIS and image processing tools/technology available on the market was accomplished. As a result to this investigation, a decision has been made that the technology and integration flexibility associated with the GIS off-the-shelf commercial software, such as ESRI Mapobjects tools and components, will provide a reasonable environment to create the system. In selecting the appropriate tools and environment for the proposed system, a special emphasis on implementation in intranet environments was made.

The functionality and interface considerations will deal with:

i- the data retrieval problems associated with identifying single-point, linear, or areal features in the raster image;

ii- relating these to their counterparts in the vector database (which would likely have been collected at different times from different imagery); and then

iii- obtaining the attributes of these vector features from the database and returning them to the end user.

More advanced queries involving buffering and user-specified polygon overlay in an Intranet environment will also be examined.

4. INTELLIGENT IMAGERY SYSTEM: ANTICIPATED SIGNIFICANCE

The proposed concept of relying on remote sensing imagery supported by a hidden vector database in a GIS as a base for analyzing and querying the real world will have a significant effect on many disciplines and applications. Some of these may be summarized as follows:

1- Maps are serving as a powerful tool for handling and analyzing spatial data. With the advanced technology presented in a Geographic Information Systems, the geographical data within any particular area of interest can be stored in separate layers. Each layer represents a theme of topologically related features (eg. Road network layer, Hydrographic features layer, Forest polygons layer, Contour layer,…etc). Complex spatial analysis for this particular area requires the combination or superimposition of all of these layers to be able to perform the spatial analysis task completely. Relying only on these map layers to perform spatial analysis tasks suffers from several weakness as follows (Derenyi and Fraser, 1996):

   i- Maps are a static representation of the real world and always out of date even before storage in a geographical database.

   ii- Superimposition of all data layers at once complicates the visual analysis performed by the analysts to pre-examine the situation at hand and might hide important spatial patterns which might lead to wrong or imperfect decision criteria. A temporary solution is to handle a few layers at a time.

   iii- Using remote sensing imagery as a backdrop underneath map layers will increase the visual interpretation of the situation at hand but only, still, in the case of handling few data layers at one time.

Consequently, the concept of querying an image covering a particular area with the support of hidden vector database layers will provide a clearer and completely detailed view. Using imagery as an interactive media with the real world will provide a synoptic view of the real world and with the support of the well organized vector database this will help to effectively and efficiently query that image.

2- Using remote sensing imagery as a interactive media has several advantages as stated by Clark et al. [1974] and Mckeown [1987]. Remote sensing imagery contains more information than vector maps. Users can better orient themselves with images rather than a map overlay, especially if they are not familiar with the area under consideration. Furthermore, superimposing map layers on an image serving as a backdrop is not the correct way of getting a maximum benefit of the heterogeneous amount of raster and vector data available nowadays. The superimposition solution might be sufficient if both the area of interest and the spatial analysis task is not complex (i.e. involves few data layers for analysis). As the complexity increases more data layers should be involved and more confusion can arise by superimposing vector and raster data. Furthermore, it will be time consuming to query a few data layers at a time. So, in order to *"on-the-fly"* query whatever data layers are available and necessary with less confusion the proposed methodology will provide a better solution.

3- One of the most important applications of combining vector data and remote sensing imagery is image classification. Digital image classification is "the process of assigning pixels to classes" (Campbell, 1995). The first step in most image classification techniques is the selection of the training areas which represent the terrain classes of interest. Training areas are usually obtained by using maps and aerial photos. As stated by Campbell 1995, the analyst is assumed to be familiar with the area of interest. Selecting the training areas is usually performed by superimposing maps over image data. Hinton [1996] stated that "… to be of maximum benefit, the system used must be able to perform the so called raster/vector intersection query (Ehlers et al., 1991), (i.e., given an image and a polygon file, which pixels fall within which polygon), without carrying out any format conversion or raster overlays/combinations". With the proposed approach we can link the pixel coordinates to vector map coordinates, query the database, and display the result directly into image pixels. As a result, the analyst will be able to select and delineate the desired training areas without either format conversion or raster/vector overlay. Furthermore, the analysts familiarity with the area is a preferable but not a mandatory requirement. The proposed intelligent imagery system will provide image classification with a fast and *"automatic"* process of selecting the training area.

4- Emmanuel [1996] mentioned that orthoimages can be used as a geographic reference layers in which spatial operations like polygon retrieval, buffer, CoGo function…etc. can be executed, and the results can be displayed. He mentioned that the orthoimage will provide a complete view of the world as well as permitting visual interpretation by the operator. In the intelligent imagery system, an investigation for the possibilities, and challenges in using orthophoto as well as other types of imagery that vary in their level of rectification as a reference layer in performing spatial queries and operations.

5- As reported by Jensen [1990], the aerial photo interpretation task is too time consuming, especially, for a large city. Also, we might have the risk that interpretation will vary between interpreters due to their different background knowledge. The proposed method of intelligent imagery will provide an on-the-fly base to help interpreters in their interpretation and reduce the risk of arriving at completely different interpretations in some cases.

The above mentioned points are far from a complete list, but give an idea about how the proposed system will improve the ability to handle raster and vector data sets in a diversity of applications.

5. RESEARCH CASES

One of the most important aspects of this research is to establish an efficient and appropriate link between the image and the vector database. This link should be on-the-fly, rather than a pre-defined link, i.e., the user should be able to identify the vector layer(s) and the image, insert some parameters, double click on a button, and start querying the image. Inappropriate links may produce slower performance, confusion, and inaccurate results. The linkage between the raster image and the vector database will be established through feature ground coordinates. The following factors should be considered in trying to establish the appropriate link between the datasets:

1- Scale: The image and the vector data covering the same area may have different scales.

2-Projection: We may have different projections systems for both data sets.

3-Coordinate system: Coordinate systems might be different for both data sets.

4-Level of image rectification: The image may be differentially rectified, partially rectified, or unrectified. Differentially rectified means that it has been corrected geometrically and also due to relief displacement, the so-called "Orthoimage". Partially rectified means that it has been corrected geometrically due to several geometric distortion factors like earth curvature, atmospheric reflection, sensor movement, etc., but not corrected due to relief displacement. Unrectified means that the image has not been rectified at all (for example, scanned aerial photo).

There are increasing levels of complexity in such an application. For example:

i-the image is differentially georectified (as with a digital orthophoto) and it shares a common coordinate system and map projection with the corresponding vector data;
ii-the image is fully georectified but is related to a different coordinate system from the vector data;
iii- and iv- the image is only partially rectified (perhaps with no corrections for relief distortion)
v-the image is not rectified, but a limited number of photo-identifiable control points are available.

In order to identify all possible levels/cases, a framework was developed as shown in Figure 3. The case in Figure 3 represents a case with the following characteristics
:

1- differentially rectified imagery (orthoimage);
2- image and vector files with different scales;
3- image and vector files with the same projection and coordinate systems.

Using the framework in Figure 3, we can identify all possible cases for combining remote sensing imagery and vector files. Figures 4 through 6 summarize the cases that intended to be investigated within this research project.

Conclusions

The proposed intelligent imagery system provides a different approach to integrate remotely sensed data with corresponding GIS vector data. The approach is based on the idea of using remote sensing imagery as a reference layer through which the user can directly retrieve spatial information, perform spatial query, and apply a restricted polygon-based spatial query on the image directly. This system will eliminate the need for vector overlays and/or vector- to – raster and raster- to- vector conversion which may hide spatial information patterns and reduce data quality. The proposed system is expected to provide a flexible tool for decision making process.

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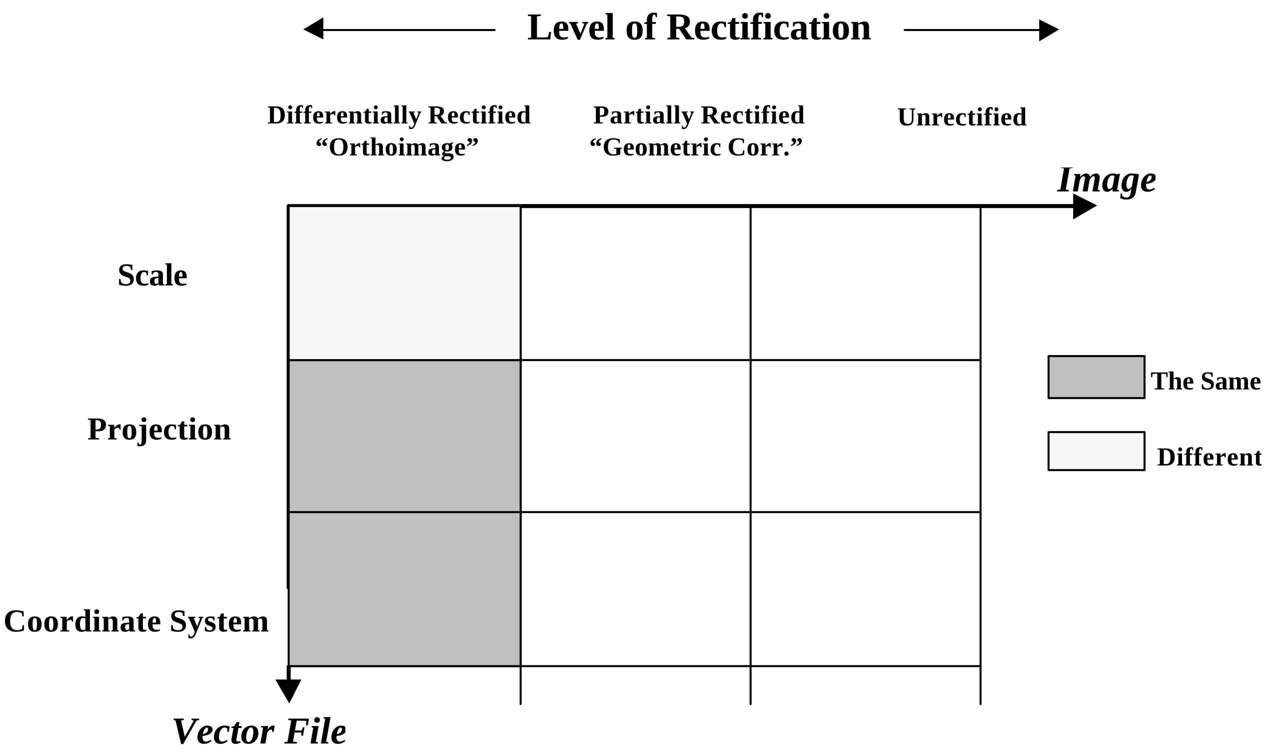

Figure 3. Framework of handling remote sensing imagery and vector files

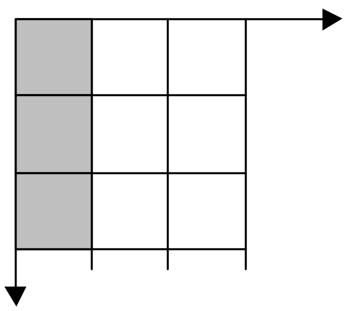

Figure 4. Research Case 1

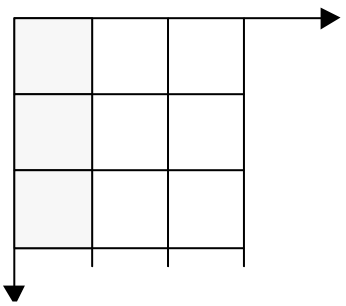

Figure 5. Research Case 2

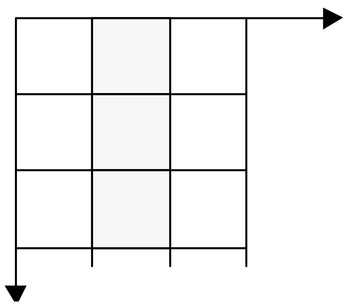

Figure 6. Research Case 3

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