# PC Network of Image Computing for Remote Sensing

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Automation of satellite remote sensing data analysis is essential if one is to utilize a massive amount of remote sensing data fully and operationally. In order to extract useful information from remotely sensed data automatically, a wide range of functions such as physical data processing, low-level numerical image processing, symbolic processing, processing of semantics, soft computing, database system operations and the generation of virtual reality need to be integrated. Furthermore, a very large amount of knowledge should be integrated. The development of such a system has usually been considered to require a vast amount of resources. However, recent advances in PC technology have made it possible to implement such a system on a LAN-based PC network system in a short time at a relatively low cost. This was accomplished through the utilization of existing information and the integration of available technology.

## INTRODUCTION

Digital image processing and analysis methods are widely used for remote sensing data analysis. Many satellites have been launched and are transmitting a massive amount of data. However, only a small portion of the observed data has been analysed and utilized with most of the data simply being archived because of various constraints on data distribution, system capacity and analysis methods. In order to utilize the acquired data fully and operationally, it is essential to increase the user population and broaden the application areas through the automation of remote sensing data analysis in a user-friendly computational environment. Such an automated system integrates spectral, spatial and semantic information and therefore requires a broad class of functions such as spatial image computing, symbolic image handling, scene simulation, soft-computing and database functions as well as traditional low-level numerical image computing functions. This system also requires extensive knowledge to be integrated into it (Iisaka and Sakurai-Amano, 1995b).

In most traditional remote sensing analysis systems, observed data are processed to produce terrain classes through a rather complicated sequential procedure. There is a one-to-one correspondence between a set of observed data and a set of terrain classes as illustrated in Figure 1. On the other hand, in our automated system, the image processing is not conventional sequential control flow type but data flow type. In the data flow type processing, an image computing algorithm is expressed in terms of operators. This makes the system more suitable for parallel program execution, which is required to implement our approach. We named the approach "Information Fusion". Many intermediate results are created and fused. Figure 2 illustrates the automated system schematically. Some examples of short-term knowledge, medium-term knowledge and long-term knowledge are shown in Table 1.

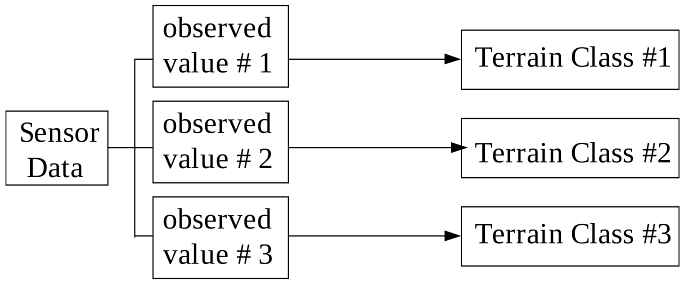


Figure 1. Traditional information extraction approach.

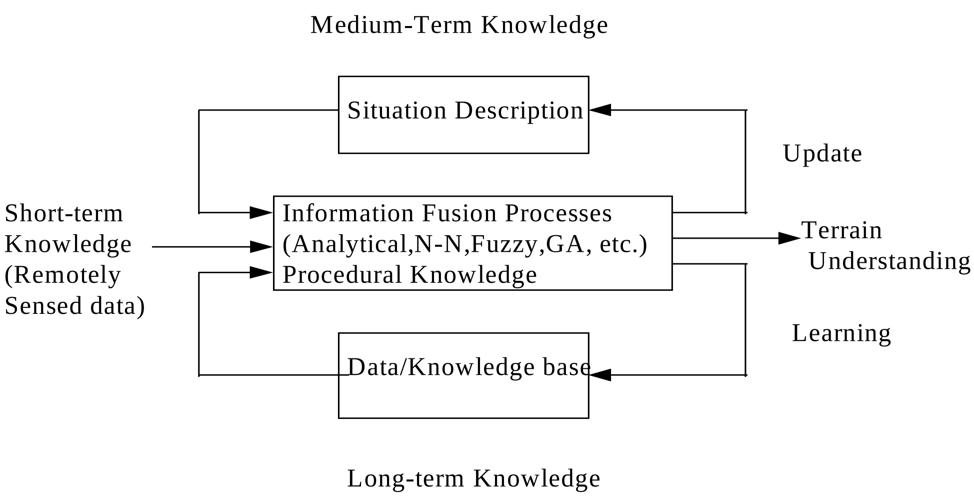


Figure 2. Information Fusion approach in the automated system.
( N-N:neural network, GA: genetic algorithms )

Table 1.
Examples of Knowledge for Information Fusion.

| |
|---|
| **Short-term knowledge**<br>- observed signals, pixel values<br>- spectral bands, wavelength of sensor, sensor geometry<br>- bright target, dark target |
| **Medium-term knowledge (situation description)**<br>- At a very low threshold, IR images show water bodies of pure water class.<br>- At a slightly higher threshold, detected water bodies may include pixel of mixed classes. (e.g. small streams) |
| **Long-term knowledge**<br>- Reflectance of water in IR region is very low.<br>- Reflectance of vegetation in IR region is very high.<br>- Seashore lines are attached to ocean.<br>- The width of roads are mostly less than 100m. |

It was proposed to implement most of the required functions for a remote sensing data analysis and terrain understanding system on a PC-based network system (Iisaka and Russell, 1989). Recent advancement of PC technologies with respect to memory size and disk capacity, computing speed, user interface, LAN (Local Area Network) functions as well as cost performance has facilitated the implementation of the system. The first stage of the implementation was reported in a previous paper (Iisaka and Sakurai-Amano, 1995b). This paper includes further development of the concept and system.

## PC NETWORK BASED COMPUTATIONAL ENVIRONMENT

Since the implementation of an automated system requires various kinds of functions as described above, it would entail a lot of manpower and huge costs if the system is developed from scratch. The capability and connectivity of PCs is now becoming comparable to that of UNIX-based workstations. PCs are superior to workstations with respect to the price of software and hardware, the user-friendliness of the interface, the variety of software including not only programs but also object libraries, and the ease of installation and maintenance. In such a general situation, a LAN-based PC network environment seems to be more favourable for the low-cost, efficient, easy implementation of an automated terrain understanding system considering the following environment. All the computer resources on the network are accessible from each PC in exactly the same way as its own resources.

1. Multi-users/analysts

   In the current stage of semi-automation for most image processing systems, there is usually more than one user/analyst engaged in remote sensing data analysis. From our experience, these users usually specialize in different phases of an analysis with some overlap.

2. Wide variety of application programs

   Numerous programs are available for various application areas or phases of terrain analysis. These programs can be distributed on selected computers depending on the user’s specialities and hardware constraints. Programs less frequently used can be made available through the network.

3. Wide variety of required functions

   Since no single software package provides every required function for an application phase, it is often necessary to combine several packages which may reside on different computers to do a task.

4. Parallel processing/distributed processing

   The efficient use of the computing power on the network can be achieved by distributing the processing to other computers on the network. Furthermore, the “Information Fusion” approach is inherently suitable for parallel processing. Some image computing software has parallel processing capability.

5. Image database and knowledge base

Image databases contain not only the original remotely sensed data but also important intermediate results and final results from each application user. Additional knowledge is required for terrain understanding. A distributed database is preferred to a centralized one with respect to the construction and maintenance of the database.

## FUNCTIONAL REQUIREMENTS FOR TERRAIN INTERPRETATION

### Physical data processing

This area includes calibration and normalization of observed physical data, improvement of signal-to-noise ratio, and correction and calibration of satellite position.

### Low level numerical image processing

The observed data can be processed as two- or multi-dimensional information. Each processed pixel is a value or a set of values without any attached physical meanings. Signal coding, compression, and image processing (that is, contrast stretching and image transformation) are included in this category. Traditional methods such as statistical analysis of image data and texture/pixel-value-based pattern classification also belong to this area.

### Spatial information processing

Spatial or morphological characteristics of various regions within an image are defined using a unified method of spectral and spatial information processing (Iisaka and Sakurai-Amano, 1995c) . Objects in an image with specific geometrical characteristics are then extracted (Iisaka et al., 1995a and b). Information extracted from this stage may feed directoly into certain applications but usually it consists of image cues such as points, groups of points, line segment, groups of line segments, areas and groups of areas.

### Symbolic processing

Processing the relation of symbols is one of the important functions of image analysis. In this case, a symbol represents a set of pixels that has a specific meaning. For example, a triangle identifies an object that consists of three vertices and three edges. Symbolic processing encompasses the structural relation and constituents of the objects.

### Semantic processing

A higher level of semantic processing is necessary to determine the significance of terrain conditions and terrain objects such as location, arrangement and association among terrain feature constituents. This requires functions to analyze the spatial association of symbolized information (Iisaka and Sakurai-Amano 1993, 1994a and b). For example among many boundaries and edges in an image, a coast line is defined as a line that bounds a sea or ocean. A bridge is a linear feature that crosses a river. Although a rule-based system (Goodenough et al. 1990) has been suggested, there is some difficulty in estimating weights for the rules.

## Soft computing

Soft-computing is a type of computing comprised with artificial nueral computing, fuzzy logic, generic algorithms and other machine intelligence and creates near-optimum solutions or approximated values within a reasonable computing time. Conventional application of computers is categorized as “hard computing”, which create precise results based on pre-defined algorithms. Although hard computing methods have dominated the computing world for a long time, most real world applications, including terrain understanding, are fundamentally soft computing problems. The system should provide soft computing capabilities such as fuzzy decision-making processes, neural networks (N-N), and genetic algorithms (GA). There are often large gaps between human concepts and reality from a hard computing point of view. Natural patterns usually deviates from a strict mathematical description and need a large tolerance. For example, although an oceanic cold ring or warm ring is often considered as a circular pattern, it is not a circle in a strictly mathematical sense (Trites 1981). The definitions of terrain classes are intrinsically fuzzy. The “bare soil” land cover class often comprises a small portion of vegetation. However, there is no clear quantitative definition for the degree of vegetation mixed in the “bare soil” class (Wang 1990). Fuzzy object presentation, fuzzy object recognition and classification functions, neural network computing with a learning capability, and genetic algorithms are included in the automated system (Iisaka and Sakurai-Amano, 1995b).

## Database

Databases store a large amount of existing knowledge including images, physical constants, tables, maps, previous observations and procedural knowledge. In order to utilize such knowledge, the system should include a database functionality.

In stead of a centralized database system, a distributed database close to each application user is preferred with respect to the construction, maintenance and flexibility of the database. Each application user is more knowledgeable about his/her own data and can maintain and update his/her own database. The database should be easy to access, easy to maintain, easy to update, reliable and complete. Using a LAN network system, files can be accessible from any computer on the network without actual file transfers.

## Visualization

Using multimedia capability, various presentation methods that visualize the results of analysis, multi-image fusion, and terrain change help facilitate scientific interpretation and assist in operational decision making.

User interface

A friendly interface is desirable to accelerate processing. Window-type interfaces and object-oriented interfaces for image processing are commercially available. As no single software package provides all the required functions, different software packages are distributed to each workstation (remote login functions are not considered in this system). Easy file sharing capability among distributed workstations is essential to apply a series of different analysis methods to a set of input images. Therefore, a good file management system capable to handle files from different platforms is necessary.

Simulation with virtual reality

Since the simulation of observed data quite often facilitates analysis, goal-driven and data-driven analysis should be provided. Since pixel values or texture in a SAR image vary depending on observing conditions, it is very difficult to define distinct terrain categories. In such a case, the accuracy of the analysis can be improved by comparing the observed data with simulated data. The degree of vegetation for an observed forest area can also be analyzed by comparing it with the simulation of various degrees of vegetation density and/or tree heights of a forest. Commercially available virtual reality functions of a terrain model (Stevens, 1989) can be integrated into the terrain understanding system.

## KNOWLEDGE AND IMAGE DATA PRESENTATION SCHEME

Knowledge required for the automated system can be categorized as short-term declarative knowledge, medium-term declarative knowledge, long-term declarative knowledge, and procedural knowledge. Table 2 shows the attributes of the knowledge classes.

Table 2.
Attributes of knowledge classes.

| **Knowledge Class** | **Attribute Association** | **Data Class** | **Learning/Forgetting Rate** |
|---|---|---|---|
| short-term declarative | sensor output (signal and pixel value) | dynamic | fast |
| medium-term declarative | situation description | dynamic | moderate |
| long-term declarative | a priori declarative knowledge | static | slow |
| **procedural** | **reasoning knowledge** | **static** | **slow** |

Images are described as two-dimensional arrays. In the automated system, a fuzzy terrain object is defined as a range of possible target types as illustrated in Figure 3.

Procedural knowledge is described in the graph shown in Figure 4.

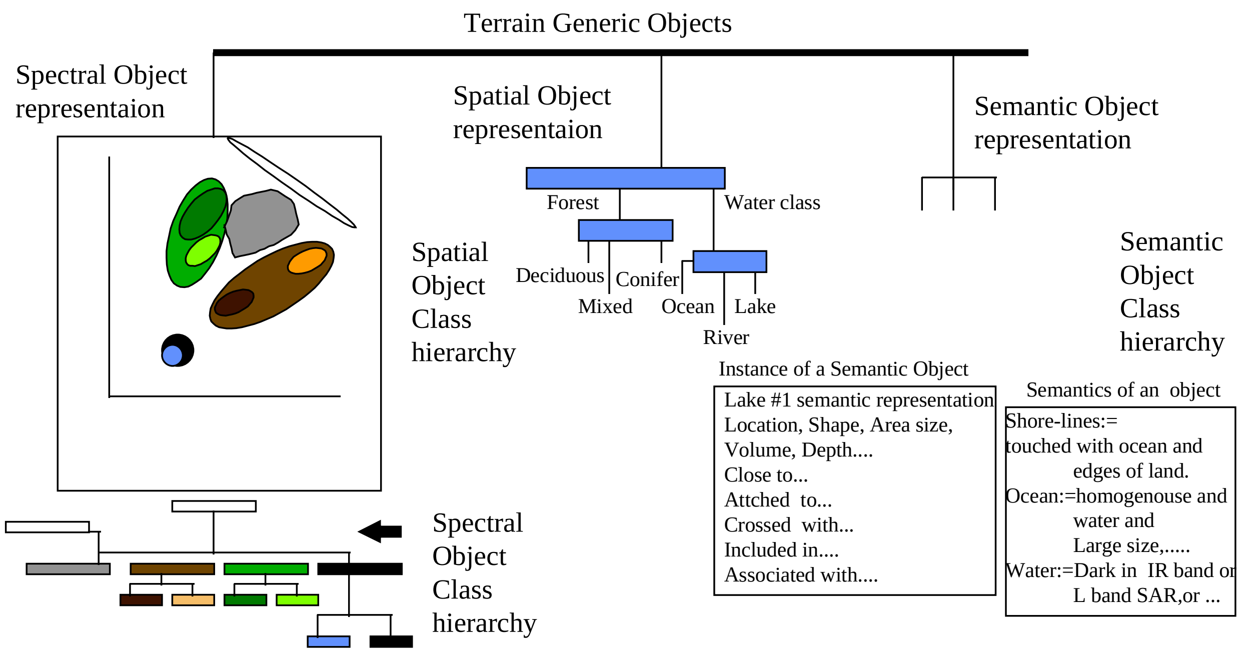


Figure 3. Relationship among spectral, spatial and semantic terrain objects.

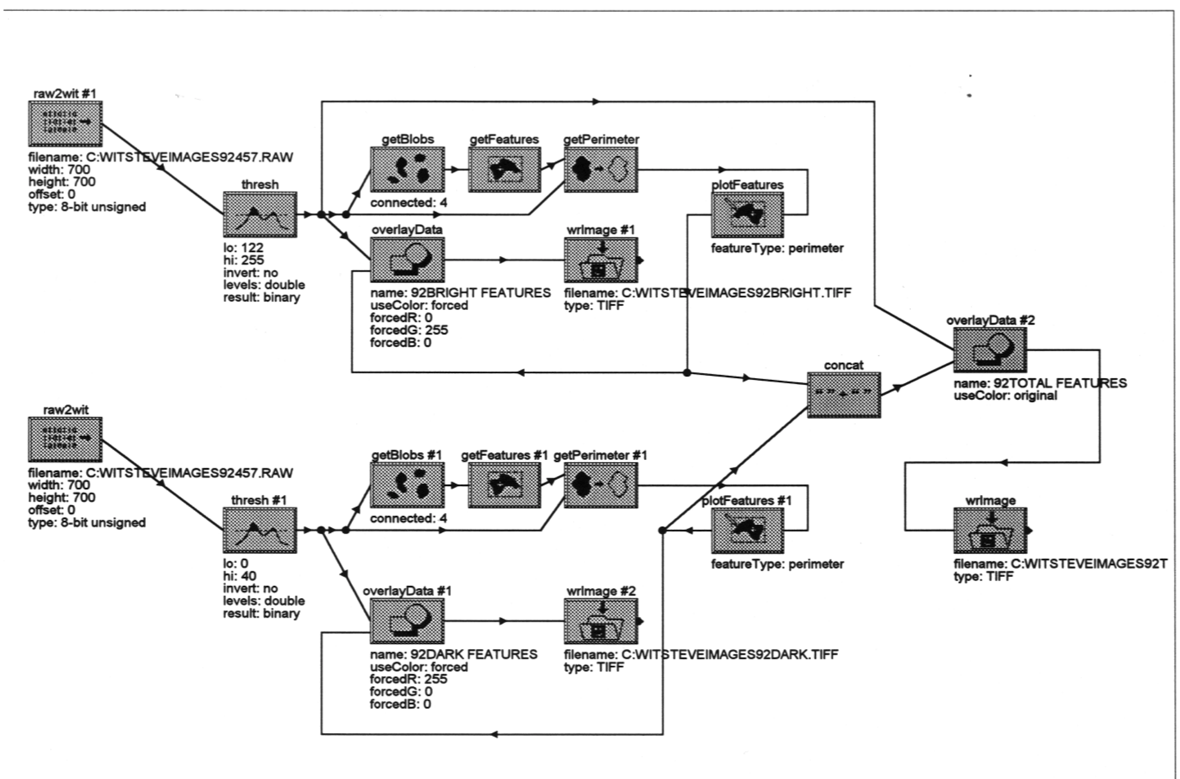

Figure 4. An example of a graphical presentation of procedural knowledge.

## SYSTEM CONFIGURATION AND IMPLEMENTATION

In order to implement economically and efficiently a system with such a wide range of functions, the system was developed on a PC-LAN environment considering the recent ever-advancing PC hardware and software technologies and cost performances. Instead of developing a system from scratch, existing software packages even in other areas such as medical image processing and machine vision were searched for and integrated into the system as much as possible. Only a few programs that are not available were developed. This reduces the burden of updating software.

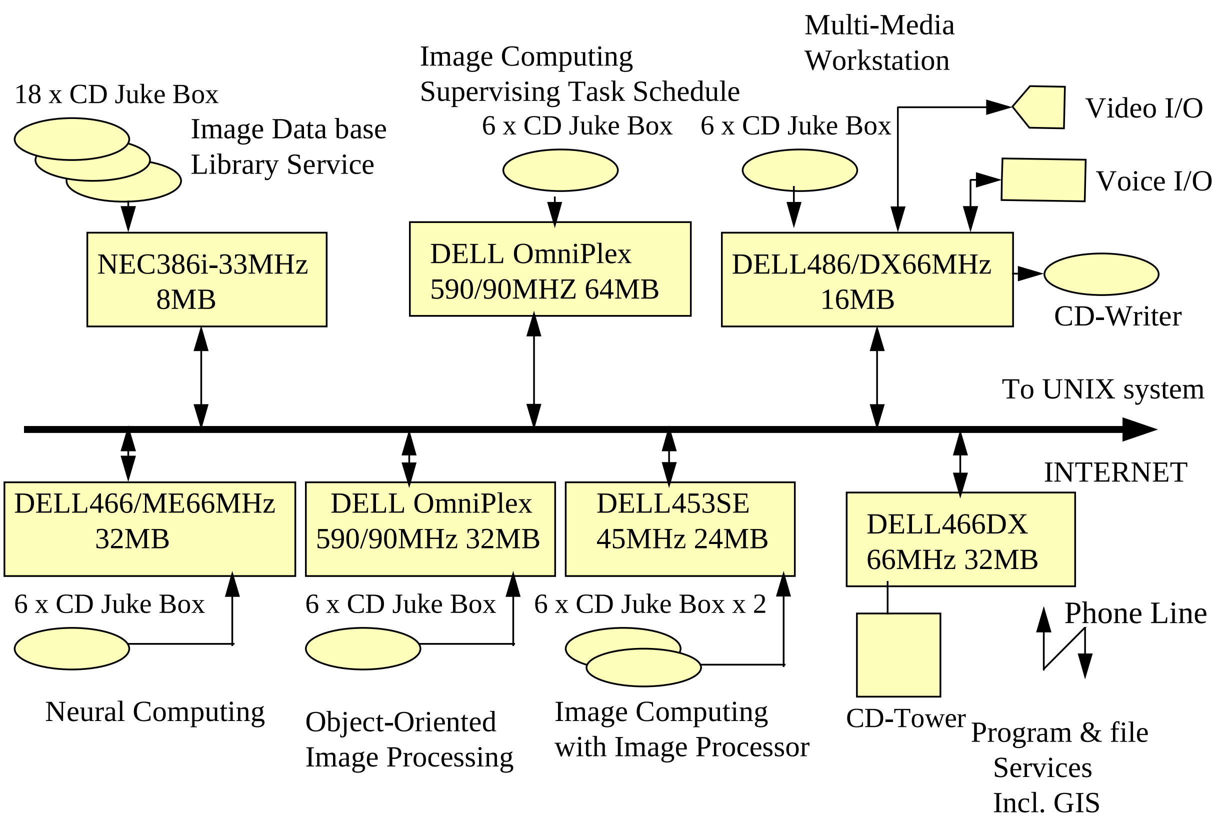


Figure 5. Configuration of the PC LAN-based terrain understanding system for remote sensing.

Current configuration of the system is shown in Figure 5. Each PC has MS WINDOWS FOR WORKGROUPS. With this environment, every device and every file is accessible from any PC. Every PC has a CD “juke-box” attached. One PC serves as the image database, to which a CD-ROM tower is attached. Currently, more than 100 CD titles store remote sensing data. Another PC serves as a multimedia station. Additional computers serve as image processing systems with different resources such as neural computing and object-oriented image processing programs.

The database functions were developed using MS-ACCESS, a commercial relational database access program. Geographic queries were implemented using a GIS package, Mapinfo. The user interface was developed using NETSCAPE, which is a popular network interface capable of retrieving and displaying images. Figure 6 shows the relation of image database entries. The database stores not only original imagery obtained from external sources but also processed results of image computing and non-image data such as tables of physical constants and geographic data. Various image formats currently exist for remote sensing data. Some are popular formats such as TIFF (Tagged Interchange File Format) and GIF (Graphic Image File), but others are not so popular and sometimes specific to the program packages. Although the system includes various image format conversion programs to handle many types, the flat file format is primarily used in the system to ensure the maximum compatibility of image data among various systems. For the purpose of image browsing, every image was compressed into JPEG (Joint Photographic Experts Group) format and stored as a thumbnail.

Final results and every important intermediate image data are stored on CD-ROMs using a local CD writer connected to the multimedia workstation.

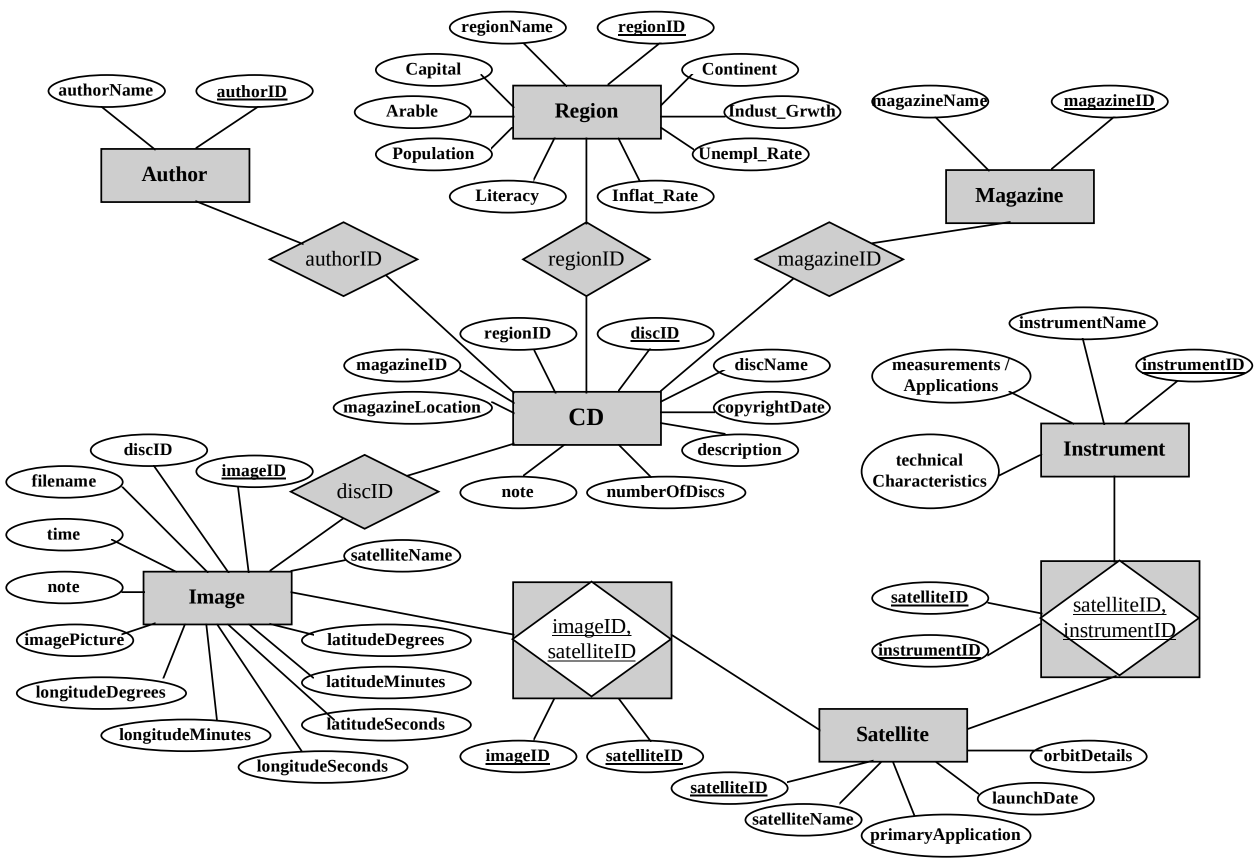


Figure 6. Image database entry design.

## SUMMARY AND CONCLUSION

This paper outlined a LAN-based system to assist automated terrain understanding using remotely sensed data. Various levels of data processing functions as well as knowledge database are required, from observed data to final terrain features of interest including spatial processing functions. Other functions such as database, display and user interface were also described.

Since we used existing software packages as much as possible, this system was implemented in quite a short time. Advantages of using commercially available software packages of PC are: (1) the system is portable to other users; (2) the system is relatively free from software maintenance; and (3) the cost of hardware and software for PCs is very inexpensive compared to that of a UNIX system.

There is some room to improve the system. The most important tasks are to identify and develop practical procedures to understand and extract terrain features of interest by combining existing functions. In addition, a natural language interface needs to be developed.

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