Journal of the Korean Society of Remote Sensing, Vol. 14, No.4, 1998, pp.376~391

Development of an Image Processing System for the Large Size High Resolution Satellite Images

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대용량 고해상 위성영상처리 시스템 개발

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Abstract

Images from satellites will have 1 to 3 meter ground resolution and will be very useful for analyzing current status of earth surface. An image processing system named GeoWatch with more intelligent image processing algorithms has been designed and implemented to support the detailed analysis of the land surface using high-resolution satellite imagery. The GeoWatch is a valuable tool for satellite image processing such as digitizing, geometric correction using ground control points, interactive enhancement, various transforms, arithmetic operations, calculating vegetation indices. It can be used for investigating various facts such as the change detection, land cover classification, capacity estimation of the industrial complex, urban information extraction, etc. using more intelligent analysis method with a variety of visual techniques. The strong points of this system are flexible algorithm-save-method for efficient handling of large size images (e.g. full scenes), automatic menu generation and powerful visual programming environment. Most of the existing image processing systems use general graphic user interfaces. In this paper we adopted visual program language for remotely sensed image processing for its powerful programmability and ease of use. This system is an integrated raster/vector analysis system and equipped with many useful functions such as vector overlay, flight simulation, 3D display, and object modeling techniques, etc. In addition to the modules for image and digital signal processing, the system provides many other utilities such as a toolbox and an interactive image editor.

Received 16 September 1998 ; Accepted 20 December 1998.

This paper also presents several cases of image analysis methods with AI (Artificial Intelligent) technique and design concept for visual programming environment.

Keywords : Remotely sensed imagery, Large scale image, Algorithm save, Visual Programming

요 약

위성의 발달에 따라 고해상영상이 등장하게 되었고 지표상태 분석에 매우 유용하게되었다. GeoWatch는 지능형 영상처리 시스템으로서, 고해상도 영상을 이용하여 디지타이징, 지리보정, 강조, 여러 가지 연산, 식생지수 분석, 등을 하여 지표면 분석 등을 할 수 있는 시스템이다. 또한 지능형 분석 방법 등 여러 가지 기법을 이용하여 변화지역분석, 토지분류, 도시정보추출 등을 수행한다. 이 시스템의 강점은 full scene 영상 같은 대용량 영상을 다룰 경우 역동적인 알고리즘 저장 방식을 채택하였고, 자동메뉴 생성, 사용자 편의를 위한 비쥬얼 프로그래밍 환경 등을 제공한다. 이 시스템은 또한 위성영상 위에 벡터를 중첩하여 분석하거나 수정 작업을 할 수 있고, 3차원 비행 시뮬레이션도 가능 하다. 이 시스템은 영상처리 모듈 외에도 영상 변환 및 수정 유틸리티 기능을 많이 제공한다. 본 논문에서는 또한 지능형 영상 분석 방법 뿐만이 아니라, 대용량처리나, 비쥬얼 프로그램을 위한 디자인 개념을 제공한다.

1. Introduction

The analysis of high-resolution imagery requires more intelligent and complex image processing technique because the ground objects are captured in detail. For example, with high resolution images, the traditional pixel operation based classification would not work very well because the variation within one land use class could be big enough to be classified as several different classes. Furthermore, the large image data size and its complex relationship with its auxiliary data require very special data modeling and efficient data management techniques. The development of an intelligent image processing technique has been one of the major research tasks among the advanced countries. Examples of these systems are IUE for computer vision and image processing and the Khoros system that includes visual environment and utilities (Konstantinides, 1994). The purpose of providing a visual language interface is to increase the productivity of researchers and application developers. By providing a more natural environment which is similar to the block diagrams that are already familiar to practitioners in the field, the visual language provides support to both beginners and experienced programmers. The GeoWatch also includes most of the image processing routines. Additionally efficient database management modules (Henry, 1991) GIS modules, model based analysis modules, terrain analysis modules and classification modules with AI technique were developed and implemented.

2. Design Concept

The configuration of the GeoWatch is shown in Figure 1. GeoWatch software can be divided into two categories; image analysis part and system management part. Image analysis part consists of image processing modules, object modeling modules, image analysis modules, GIS modules, workspace handling modules, and terrain analysis modules. System management part consists of utility modules, system management modules, and DB management modules. Design emphasis of GeoWatch was put on the user friendliness, good visualization and expandability to ensure efficient use of the system and smooth expansion to a more advanced system in the future (Hibbard, 1988). Figure 2 shows the image processing system configuration. User can operate the processes through two GUI methods: visual processing and menu-driven processing. A program which interprets the textual script automatically generates the user interface. The visual processing provides more flexible and dynamic means of handling the image processing modules. Figure 3 shows detailed diagram of menu generator. The parser analyzes the pane structure and

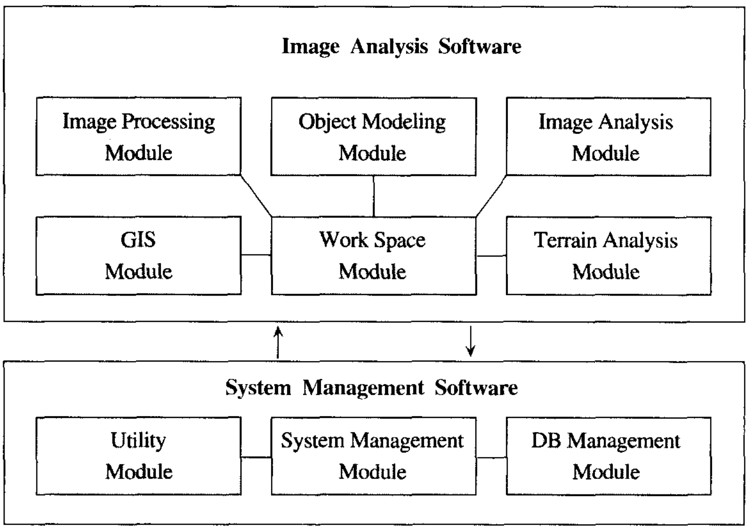

Fig. 1. GeoWatch Software Configuration. GeoWatch can be divided to two major softwares; the image analysis part and the system management part. Image analysis software is mainly composed of the image and the spatial analysis modules while the system management software is composed of the system interface modules and the utility modules.

calls the menu pane generator to generate the menu and set the parameters. This paper has emphasis on intelligent image analysis system with visual programming technique, efficient programming technique and large size image processing technique.

The highlight for the consideration points in design process are as follows:

- Large size image processing with an algorithm-save-method
- Visual programming environment
- Menu generator to save the user interface programming effort

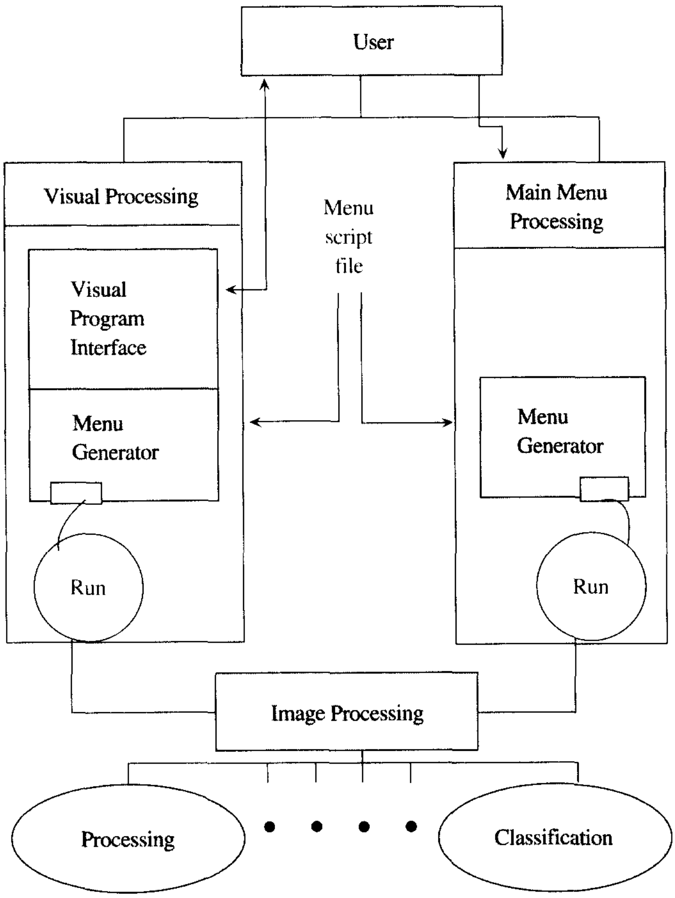

Fig. 2. Image Processing System Configuration. The user interface is implemented in the window menu system and the visual processing method.

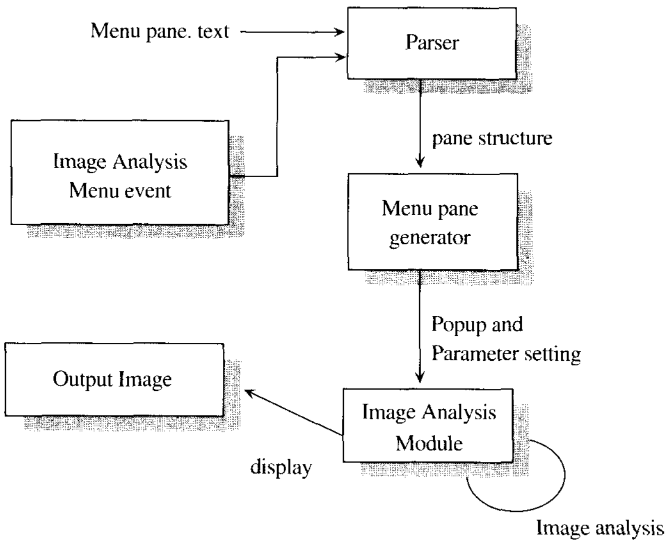

Fig. 3. Menu Generator. The parser analyzes the pane structure and calls the menu pane generator to generate the menu and set the parameters

3. Geo-Watch System Implementation

The specialized image analysis modules as well as general image processing modules have been implemented. The specialized functions of the system include recursive GCP marking, intelligent recognition and classification using various features, wavelet transforms and neural networks, very efficient database query scheme available during any image processing operation, handy report generation tool, etc. Using our system, we can present spatial 3D viewing simulation, flood inundation analysis, change detection, land use classification, estimation of city population, and estimation of industrial complex capacity. In this system ORACLE DBMS was adopted as a database management system and various information such as image names, target object information, map names, airplane flight plot information, and GIS topology data have been registered in the database system. However, other commercially available RDBMS can be connected to the system with minor interface work. Various methods for retrieving the images such as using geographic name, clicking area from the displayed map, entering the coordinates of the area, or using a file selection box are implemented. As an integrated raster/vector analysis system, GIS based analysis modules, vector overlay, flight simulation, 3D display, and object modeling techniques are also implemented. In addition to the modules for image and digital

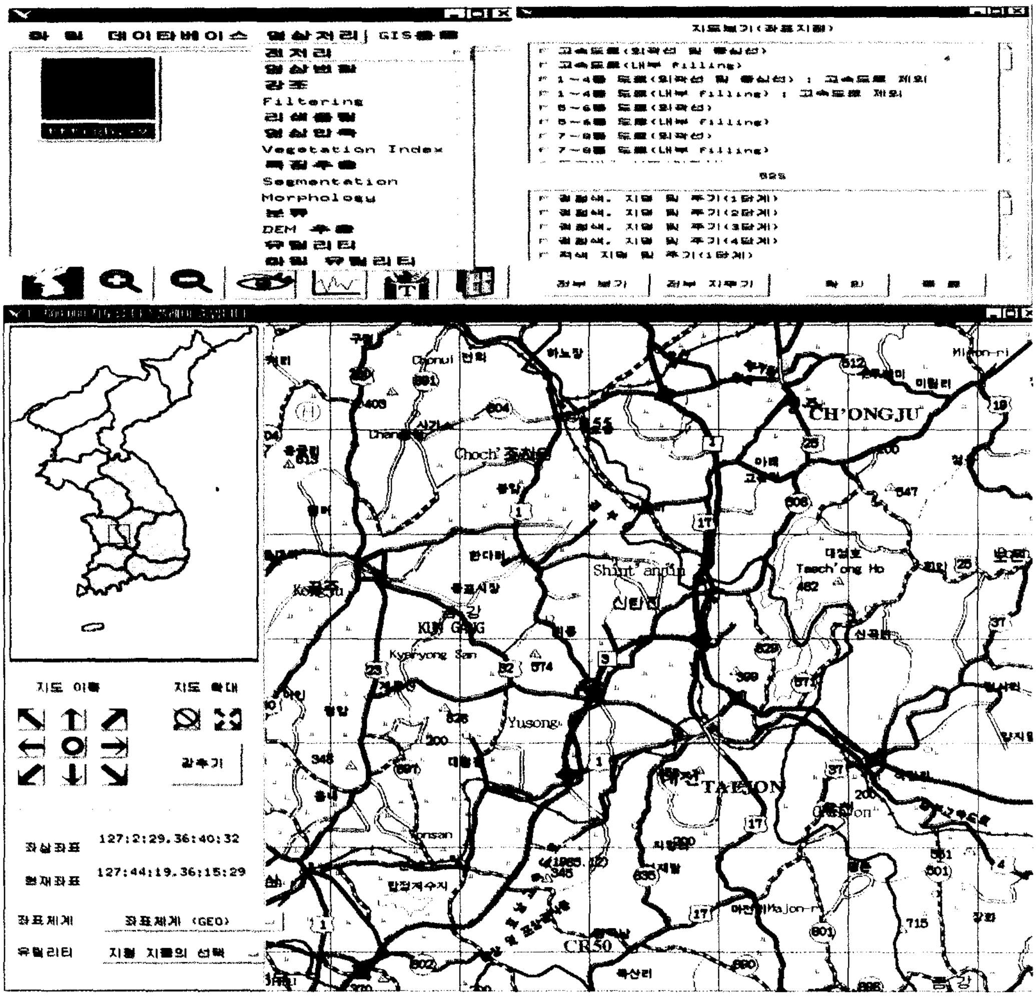

Fig. 4. Main menu of the GeoWatch system. Main menu consists of file management, database, image processing, GIS and utility buttons. The window displays an image box with sub-sampled image, a pull-down sub-menu, a file handling box, and a digitized map. The map represents a raster map with 64 layers and can be used to select the area of interest of the satellite images to be retrieved from database.

signal processing, the system provides many other interactive utilities such as a toolbox, an interactive image editor. Figure 4 shows the main menu of the GeoWatch system.

Figure 4 shows the main menu of the GeoWatch system. Main menu consists of file management, database, image processing, GIS and utility menus. The map represents a raster map with 64 layers and can be displayed with scale of 1:1,000,000 to 1:50,000.

1) System configuration

An Ultra workstation with Solaris2.5 equipped with a digitizer was used as the platform for this system. Table. 1 shows the GeoWatch development environment. The minimum user platform to process full scene would require 256MB main memory and 5GB HDD. The optimum configuration would be 512MB main memory and 10GB HDD. The following are the specialized functions in our system.

2) On-screen GCP correction

We used a semi automated geometric correction method that can correct the geometric distortion of satellite images by recursive GCP position prediction. This method can predict the next corresponding points in the image to be corrected by setting up numerical relationship between the two images using three pairs of the control points. This method saves time to find corresponding match point in the other image when a new control point is selected from one image. After all the control points are selected and marked on the displayed images, the scene to scene registration and geometric correction is performed. This module was implemented on Ultra with the Micro-Grid III digitizer.

Table 1. GeoWatch User Environment

Items	Configuration
Main Device	• CPU : 64bits, 167MHz, - Main Memory : 2 GB - HDD : 20GB Monitor : 20inch, 24bits color and 3D graphics (Creator Accelerate Graphic Board)
Storage Device	• CD-ROM Driver • 3.5inch FDD • 4 mm DAT • 16GB External HDD 8
Input/Output Device	• Digitizer(CalComp사) : 36″ × 24″ • Printer(HP Laserjet 4 Mplus급) - 600 dpi, Postscript support
Software environment	• O/S: Solaris 2.5 • Unix and Motif (Korean version) • C, C++ Compiler • GUI development toolkit (DB-Uimx/X 2.9) • ORACLE DBMS ver.7.3. : pro C, SQL Plus, Forms • X emulator

3) Recognition and Classification with AI techniques

In our system automatic target recognition that is invariant to translation, rotation, and scale transformation is achieved by a neural network based approach using geometrical moment and Zernike moment(Kim, 1995; Kim, 1996). This process has three stages: preprocessing, feature

Fig. 5. Object Recognition Using Neural Network with Zernike Moment Features. The house with arrow mark from was recognized using neural network with Zernike moment features.

extraction and classification. For the preprocessing step, the morphological as well as spatial filtering were applied to suppress the noise. For the feature extraction Zernike moments (Khotanzad, 1990) are adopted. For the classification phase, the Multi-layer Perceptron (MLP), which is trained by a back-propagation learning algorithm, is used (Mather, 1987). Figure 5 shows the results of object recognition and the house with arrow mark from was recognized using neural network with Zernike moment features.

For classification, the remotely sensed data have often led to unsatisfactory results. The parametric procedures such as the Maximum Likelihood Classifier are statistically stable and robust. However, they sometimes lack flexibility and the capability of making correct data estimates. On the other hand, non-parametric classifiers are generally sensitive to distribution of anomalies and dependent on training sample size. These problems can be overcome by providing prior probabilities derived from a non parametric strategies presented using a Kohonen neural network and multi-layer neural network with a back-propagation algorithm (Pasquariello, 1992; Johnsson, 1994; Blonda, 1994; Tenorio, 1990; Yoshida, 1994). Figure 6 shows the classification results of SPOT image of Taejon Area. After selecting a training area, a three-layered neural network was used. The classification patterns adopted here are 4 classes of water, field, forest and urban. The three-layered neural network has 5 neurons at input layer and 4 neurons at output

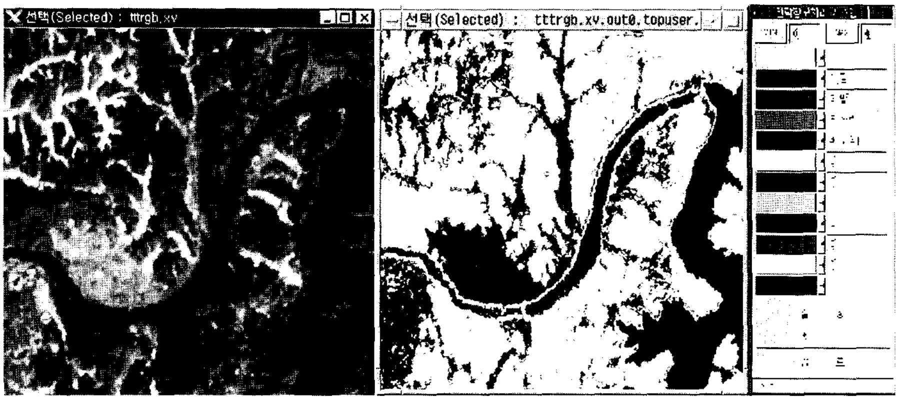

Fig. 6. Classification Example Using Neural Network Classifier. The test area is a SPOT image of 1997 of Taejon City. The input image size is 512 by 512 with 3-band resolution. After selecting a training area, a three-layered neural network was used. The classification patterns adopted here are 4 classes of water, field, forest and urban

layer. The learning rate of this experiment is 0.2, the number of hidden nodes of neural network is 39 and the iteration time is set to 50,000. The time used for training depends on the number of iteration and the execution time is less than 2 minutes with $512 \times 512 \times 3$channel image with neural network method and 5 minutes with Maximum likelihood method.

Using the features from wavelet frames, our system provides an attractive tool for the characterization of texture properties. The spatial frequency and orientation are fundamental parameters of visual texture processing(Mallat, 1989; Unser, 1995), especially with respect to wavelet frame' s localization properties in the space-frequency plane. One of the main points of this work has been to demonstrate that the wavelet transform provides an attractive tool for the characterization of texture properties. The multi-resolution properties of the wavelet transform are beneficial for texture discrimination. In many cases, a multi-cycle feature extraction led to better results than a single resolution analysis with the traditional co-occurrence method. Quantitative comparison of conventional MLC (Maximum Likelihood Classifier) versus MLP classifier indicates that the conventional MLC was less capable of discriminating texture classes than the MLP classifier. It is especially true in the case when the input data is noisy. But if the original texture is quite homogeneous, the result of MLC is as good as MLP. In analyzing he texture images with noise, MLP with enhanced wavelet frame method proved to be a better approach than the conventional MLC and co-occurrence method. (Kim, 1995; Kim, 1997).

4) GIS Integration and 3D Display

The integrated Vector/Raster based geographic information modules were also implemented in GeoWatch. The GIS modules includes topology building function, buffering, overlaying raster to vector as well as vector to raster, unlimited zooming, and many useful functions like node, arc, polygon buffering, dangling node elimination, snap node , etc. Figure 7 shows the 3D display of Ham-Heung area of North Korea. With this image we can have virtual experience of visiting that area.

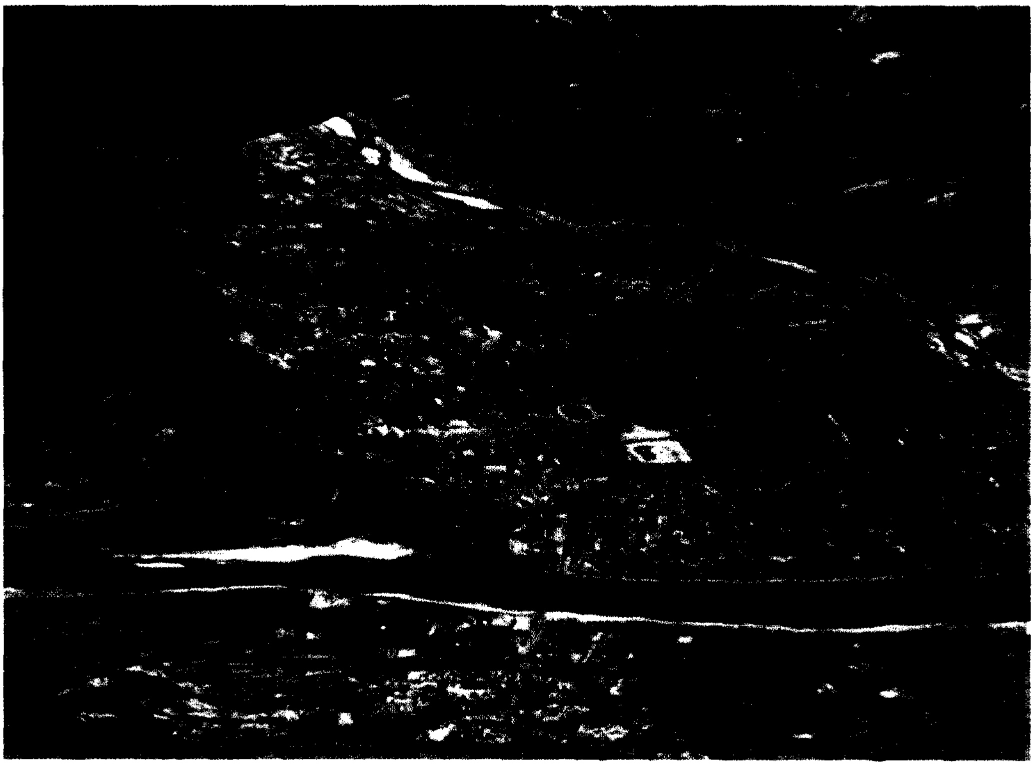

Fig. 7. 3D Image of Flight Simulation of Ham-Heung City Area Using DEM and Russian Satellite Image

4. System Functionality

Table. 2 shows the complete function list of the GeoWatch software.

Table. 2. GeoWatch Software Function List

File Management		New File, Open File, Open Other Format, File Save, Save Other Format, File Delete
System Utility		Window Close, Coordinate Display(ON/OFF), Display Pixel Info, Display File Info, Update Geo-Coordinates, Map Movement, Map Zoom , Demo Slide Display, Image Print
Map Display	Coordinate System	UTM 52S, UTM 51S , Geo-coordinate, (MGRS), WGS-84 Ellipsoid
	Map Display Utility	Object Selection, Input Coordinate, ZOOM IN, ZOOM OUT, Whole Image Display
Tool Box		Draw Box, UNDO, Erase, Free Draw, TEXT, Draw Polygon, Draw Circle, Draw Ellipse, Draw Line, Draw Arrows, Option Change
Popup on Map		Remotely Sensed Image Search on Map, Aerial Image Search on Map, Object Search on Map
Popup on Image		Object Display, Map Selection, Image Selection, Object Display End, Image Zoom Ratio Adjust
DB Management		CODE Management, Object Info-management, Map Info-management, Map Dictionary Management, Remotely Sensed Imagery Management, Aerial Image Info-management, Flight Plot Management, Report Info-management
DB Search		Object Search with Remotely Sensed Imagery, Object Search with Aerial Image
DB Search on Map		Regional Name
Pre-processing	Geometric Correction	Re-sampling , GCP Correction for Image-to-Image
	Radiometric Correction	Line Replacement, De-striping
	Digitizing	Re-sampling , GCP Correction for Image-to-Map
Re-sampling	Offline Resample	
	Offline GCP	
Image Transformation	Arithmetic	Unary: Abs Value, Logarithm, Exponential, Square root, Offset, Scale, Normalize, Not, Invert, Floor, Substitute, Clip, Conjugate
		Binary: Addition, Subtraction, Multiplication, Division, Absolute Difference, Blend Images
		Logical: And, Or, Xor, Right Shift, Left Shift, Replace
		Matrix: Invert Matrix, Transpose, Single value , Decomposition, Eigenvalues /Vectors, Matrix Multiply, LU Factorization
	PCA (Principal Component Analysis)	
	Color Transform	RGB to HLS, RGB to HSV, RGB to Indexed, Indexed to RGB
	FFT	Fast Fourier Transform
	Wavelet	Wavelet Transform
	Hardamard	
Enhancement	Off-lineEnhancement	Equalization, Stretch, Enhance Patch, Local Enhancement, Window Eq/Str, Enhancement
	On-line Histogram	Interactive histogram display, Information Graphic, Enhancement-Entire(Linear, Equalize, Normalization, Rayleigh, Exponential, Logarithm), Enhancement-Local-Path, Adjust-Bright/Contrast, Adjust-Density, Adjust-Infrequent, Adjust-Inverse, Adjust-Threshold, Multi-Two_D_Hist, Multi-Matching

Filtering	Spatial domain Filtering	Mean, Median (Quick sort), Median (Histogram), Mode, Laplacian, Roberts, Sobel, DRF edge extraction, GEF edge extraction, SDEF edge extraction, Speckle removal, 2D convolution, User Defined Kernel
	Frequency Filtering	Low-Pass, High-Pass, Band-Pass, Band-Reject, Inverse Filter, Wiener Restoration
Image Compression	Lossy Compression	DCT, Quantization, Huffman Coding
	Lossless Compression	
Vegetation Index	MSStsc (MSS Tasselled Cap), SPOTtsc (SPOT Tasselled Cap), TMtsc (TM Tasseled Cap), NDI, TVI(Transformed Vegetation Index)	
Feature Extraction	Shape Analysis, Spatial Analysis, Fractal Analysis, Fractal Dimension, Texture Extraction, Polygonal Approximation Inundation Analysis	
Inundation Analysis	Area of Dam or Flooded region is calculated and displayed	
Segmentation	Threshold, Edge closing, Dynamic Threshold, Border Distance, Medial Axis Transform	
Morphology	Morphology Kernel Create, Erosion, Dilation, Conditional Dilation, Opening (Dilation after Erosion), Closing (Erosion after Dilation), Skeletonization, Edge Extraction, Region Growing	
Classification	K-MEANS, ISO2, Maximum Likelihood Classifier, Vector Quantization, Pseudo Color Setting, Labeling Ground Truth Data Generation, Area sampling, Class Rate Calculation	
Channel Manipulation	Band-split to One channel, Band-split to Multi-channel, Band Combine, SPOT Image Extraction	
File Utility	Sub-region	Extract Sub-image, Sample on Line, Insert Sub-image, Extract Center, Pad Image
	Geometric Manipulation	Geometric manipulation: Shrink Image, Expand Image, Resize Image, Rotate Image. Transpose Image, Flip Image
	File Conversion	Data Conversion: Data type Conversion, Real to Complex, Complex to Real
	Standard Format	Raster to VIFF, Bitmap to VIFF, TGA to VIFF PBM to VIFF, TIFF to VIFF, Matrix to VIFF, VIFF to Raster, VIFF to Bitmap, Raw to VIFF, VIFF to PBM, VIFF to Matrix, VIFF to Raw, VIFF to TIFF
	Remote / GIS	BIG to VIFF, DLG to VIFF, DEM to VIFF, ELAS to VIFF, ELAS Info, VIFF to BIG, LAT/LON to UTM
DEM File Extraction	Digital Elevation Model Data Extraction	
GIS Analysis	Vector Data Generation	On Screen Digitizing, Select, Delete, Save
	Vector Data Processing	Dat Format, Dat Open, DXF Open, Close, Dat Save, DXF Save, SELECT MASK, Mask File Save, Copy, Cut, Move, Undo, Node Selection, Arc Selection, Polygon Selection, Snap Node, Snap Vertex, Arc Separation, Dangling Arc Elimination, Topology Generation, Node Buffering, Arc Buffering, Polygon Buffering
	Vector Data Overlay	Overlay File Open, Node Identity, Arc Identity, Polygon Identity, Node Intersect , Arc Intersect, Polygon Intersect , Polygon Union
Flight Simulation	Flight Simulation	Planning Flight Simulation: Path Planning, Flight Start, Path Generation Flight Path, Elevation setting, Test Flight, 3D Parameter Setting
	3D Image Generation	3D Parameter Setting

5. Visual Programming

The visual programming interface is shown in Figure 8. Data flow is implemented with a directed graph, where each node represents an operator or function and each directed arc represents a path(Hunt 1990; singh, 1992; Myers,1986 Hils, 1992; Kiper, 1996). Parameters for each node can be modified. Figure 9 shows the image processing sequence in visual programming environment. Our visual programming contains module manager, menu generator and image processing modules.

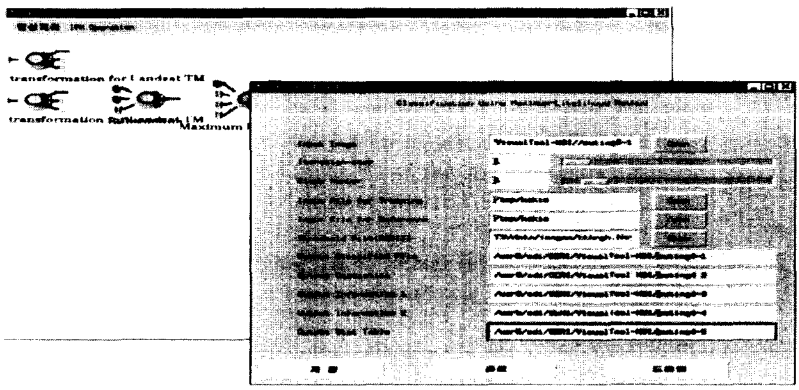

Fig. 8. Parameter Setting in Visual Programming Environment. Data flow is implemented with a directed graph, where each node represents an operator or function and each directed arc represents a path.

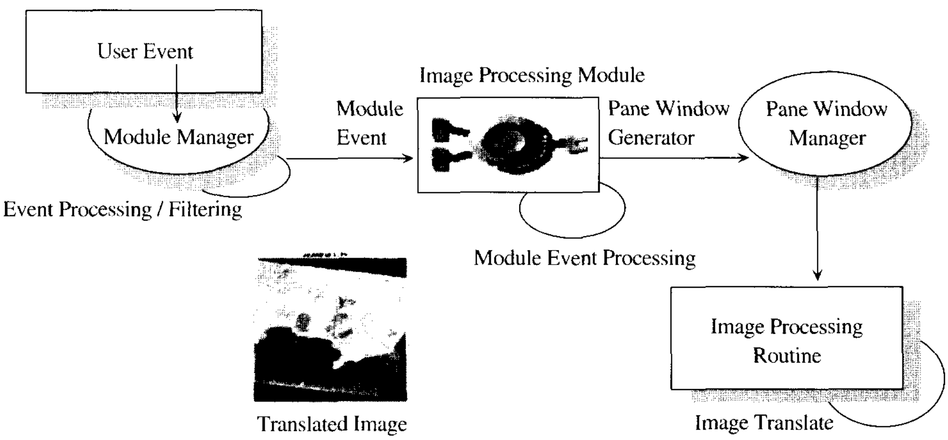

Fig. 9. Image Processing Sequence in Visual Environment. Our visual programming contains module manager, menu generator and image processing modules.

6. Flexible Handling of Large Size Image

Applying analytical algorithm to the image loaded in the memory is fast and easy to operate. However, processing several large size images (i.e. full scene) in memory, memory management problem will occur. Thus, a flexible and efficient handling method for large size image needs to be implemented. Figure 10 shows efficient large size image processing procedure. The new concept was proposed to use disk access resample and algorithm save method. The first step of this method is to sub-sample the large images from the disk to the reasonable size and load it to the memory. Several analytical algorithms are applied to the sub-sampled image data before the best-fit algorithm is selected for a specific purpose. When the results of analysis is satisfactory, then the algorithm and the analysis parameters are saved. Later the saved algorithm can be recalled and the analyzing operation can be applied to the large size image data stored in the disk. User also can have options to apply the selected algorithms to the full size image file residing in the disk to get correct statistical results. To make this algorithm-save-method a successful tool, the techniques for the efficient file management, memory management and window management were developed and implemented. The file manager extracts the area of interest specified by window manager and dynamically resample the image to fit into display window. The algorithm manager remembers all the steps occurred for the resampled images. If users move to different area of interest, the window manager repeats all the saved operations for the different image. This method is much faster for very large size images , for example, larger than 300 MB images

7. Conclusion

This paper presented a design concept and functions of GeoWatch with emphasis on an intelligent image analysis, large size image processing and visual programming. The user interface is automatically generated by program with interpretation of the textual script and algorithm sequences are saved for the large size image processing. Data flow visual programming was integrated to be an efficient analysis tool for image processing system.

The GeoWatch system is built on top of the Oracle DBMS. However, with minor interface work, other commercial RDBMS can be also used. The techniques which integrates remotely sensed images and GIS data such as precision registration, overlay, and on-line editing were also implemented. The user interface is automatically generated by program with interpretation of the textual script. In the future, data flow in visual programming should be integrated to be an efficient development tool for image processing system. This software is expected to contribute much to the analysis of the upcoming high-resolution satellite imagery. The developed software is in the stage of beta test and will be released to the users by the middle of this year.

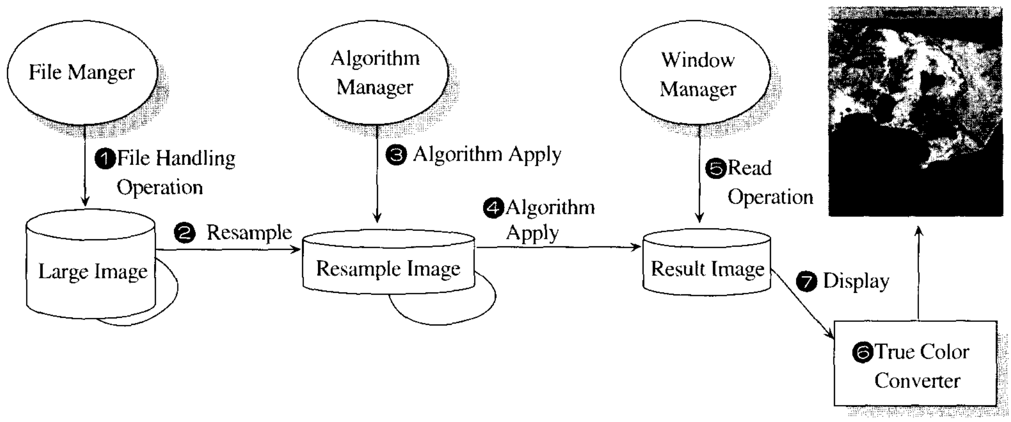

Fig. 10. Algorithm-Save-Method for the Large Size Image Processing

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