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Applicability of Geo-spatial Processing Open Sources to Geographic Object-based Image Analysis (GEOBIA)

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Abstract : At present, GEOBIA (Geographic Object-based Image Analysis), heir of OBIA (Object-based Image Analysis), is regarded as an important methodology by object-oriented paradigm for remote sensing, dealing with geo-objects related to image segmentation and classification in the different view point of pixel-based processing. This also helps to directly link to GIS applications. Thus, GEOBIA software is on the booming. The main theme of this study is to look into the applicability of geo-spatial processing open source to GEOBIA. However, there is no few fully featured open source for GEOBIA which needs complicated schemes and algorithms, till. It was carried out to implement a preliminary system for GEOBIA running an integrated and user-oriented environment. This work was performed by using various open sources such as OTB or PostgreSQL/PostGIS. Some points are different from the widely-used proprietary GEOBIA software. In this system, geo-objects are not file-based ones, but tightly linked with GIS layers in spatial database management system. The mean shift algorithm with parameters associated with spatial similarities or homogeneities is used for image segmentation. For classification process in this work, tree-based model of hierarchical network composing parent and child nodes is implemented by attribute join in the semi-automatic mode, unlike traditional image-based classification. Of course, this integrated GEOBIA system is on the progressing stage, and further works are necessary. It is expected that this approach helps to develop and to extend new applications such as urban mapping or change detection linked to GIS data sets using GEOBIA.

Key Words : GEOBIA, Open Source, OTB, Segmentation, Spatial Database

1. INTRODUCTION

According to term definition in Wikipedia, OBIA, an acronym of Object-Based Image Analysis, is a sub-discipline of GIScience devoted to partitioning remote sensing imagery into meaningful image-objects, and assessing their characteristics through spatial, spectral and temporal scale. At its most fundamental level, OBIA requires image segmentation, attribution, classification and the ability to query and link individual objects as known as segments in space and time.

In an introduction to OBIA for remote sensing by Lang *et al.* (2006), Hay and Castilla (2006) analyzed

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SWOT (Strength, Weakness, Opportunity, and Threat) with respect to OBIA topic. Technical processing and skill using object-oriented paradigm and concerned software was published in Navulur (2006). While, Jakubowski (2007) briefly summarized some open sources related to segmentation process for system implementation of OBIA, but most of them are not widely used. Lang (2009) introduced landscape analysis scheme with the OBIA criteria. Blaschke (2010) summarized OBIA principle and its applications, and turned out that OBIA has the power to successfully tackle with increasing complexity of image contents. Addink and Coillie (2010) discussed general aspect of OBIA and its wide expansion. Blaschke *et al.* (2010) explained development of OBIA theories and basic concepts established for couple of decades. Michel *et al.* (2010) presented OBIA implementation scheme by supervised classification based on attributes with SVM (Support Vector Machine) Algorithm using Orfeo Toolbox (OTB), open source for remote sensing. Despite these advancements and numerous applications in OBIA, there are domestically some cases studies such as Lee *et al.* (2007) and Yoon (2007).

From the mid 2000s, OBIA community held the specialized workshop in every two years; recently, OBIA changes GEOBIA which stands for Geographic Object-based Image Analysis, emphasized on geo-objects, and this term first proposed GEOBIA by Hay and Castilla (2006).

They explained that this term is a sub-discipline of GIS(Geographic Information Systems) devoted to developing automated methods to partition remote sensing imagery into meaningful image-object, and assessing their characteristics through spatial, spectral and temporal scales, so as to generate new geographic information in the GIS-ready format. This reflects that OBIA method provides possibility for tight linkage both remote sensing and GIS. Hereafter, the term GEOBIA is used in this study.

As for the software with the main features of GEOBIA processing and algorithms, it is known that eCognition® software by Germany-based Definiens company (http://www.definiens.com) is the first and only specialized one. This software is inclined to be regarded as a kind of stereotype for OBIA. However, open source project teams also provide GEOBIA processing, and some results have been reported, but most cases are limited to parts of realization for object-orientation paradigm, which is compared to conventional pixel-based analysis.

The purpose of this study is to implement a preliminary system for GEOBIA running an integrated and user-oriented environment, with some features distinguished from eCognition software. This implementation is totally based on various open sources to study applicability of open source to GEOBIA. In this implementation, geo-objects are not file-based ones, but tightly linked ones with spatial databases. With remote sensing images, GIS layers are also considered into object classification. However, in this implementation, segmentation variables for determining similarity are limited to spatial characteristics for mean shift algorithm for image segmentation. It is clear that GEOBIA is regarded as one of most advanced and prominent research fields in the geo-spatial domain. Thus, various approaches are needed for the actual application implementation. The main contents of this study are GEOBIA overview and a preliminary implementation, not final product with full featured GEOBIA functionalities compared to eCognition software though, to examine GEOBIA using geo-spatial processing open sources with some discussion for further works.

2. GEOBIA: STATE OF THE ART

The conventional image processing which means pixel-based analysis and this GEOBIA differ from the starting point. Pixel-oriented processing usually has some limitations: problems when dealing with rich information, inappropriate scale of work, speckles or noises caused by salt and pepper effect, inaccurate with elements of similar spectral behaviour. Basically, GEOBIA can be alternative scheme to overcome these limitations.

First all, it is necessary to define the term object in GEOBIA. Object involves pixels being grouped into objects based on either something similar or other external variables. The concept of objects is more natural to humans than that of pixels, in the image interpretation and analysis. Many variables may be determined, categorized as spectral, shape and neighbourhood. However, this definition is for image-object.

Castilla and Hay in Blaschke *et al.* (2010) also defined image-object as a discrete region of a digital image that is internally coherent and different from its surroundings. While, they also defined geo-object as a bound geographic region that can be identified for a period of time as the referent of a geographic term. In fact, most GEOBIA applications practically use the mixed concept of these terms, and objects can be ideally characterized with the following elements: color, size, shape such as squareness, roundness, or length/width ratio, texture of contrast, homogeneity, dissimilarity, context related to its neighbour, and so forth. Moreover, examples of spectral variables are mean value and standard deviation of a specific spectral band; shape variables include size, perimeter and compactness; neighbourhood variables indicate, for example, the mean difference of an object compared to darker ones. Each object is also part of a super object or parent object, obtained by combining several neighbouring objects into one larger, and each can be subdivided into smaller objects containing detailed information or instances. Table 1 shows image-object properties in eCognition OBIA approach, being summarized in Navulur (2006).

An OBIA application generally realizes through several components or steps: formulization of object composing factors, segmentation from target images, object labelling and levelling from segmented features, classification for analysis, and accuracy evaluation, as well as other miscellaneous things. Each step can be realized in the various approaches and different implementation schemes.

Fig. 1 shows a simple and general processing case for GEOBIA. As for segmentation scheme for object extraction of GEOBIA, it should produce highly homogeneous segments for the optimal separation and representation of image regions and should be universal and applicable to a large number of different data types and problems. As well, segmentation results should be reproducible. For GEOBIA, feature segmentation based on certain homogeneity feature which is predominant in the

Table 1. Image-object properties in OBIA approach, summarized in Navulur (2006)

Property type	Contents
Layer value	NIR, Red, Green, Blue, and so forth
Shape	Area, Length, Width, Compactness, Elliptic fit, Rectangle fit, Border length, Shape index, Density, Mean direction, Asymmetry, and so forth
Class-related	Relation to neighbour objects, Relation to sub-objects, Relation to super-objects, Membership, Classification value, and so forth
GLCM-based Texture	Homogeneity, Contrast, Dissimilarity, Entropy, Angular second moment, and so forth

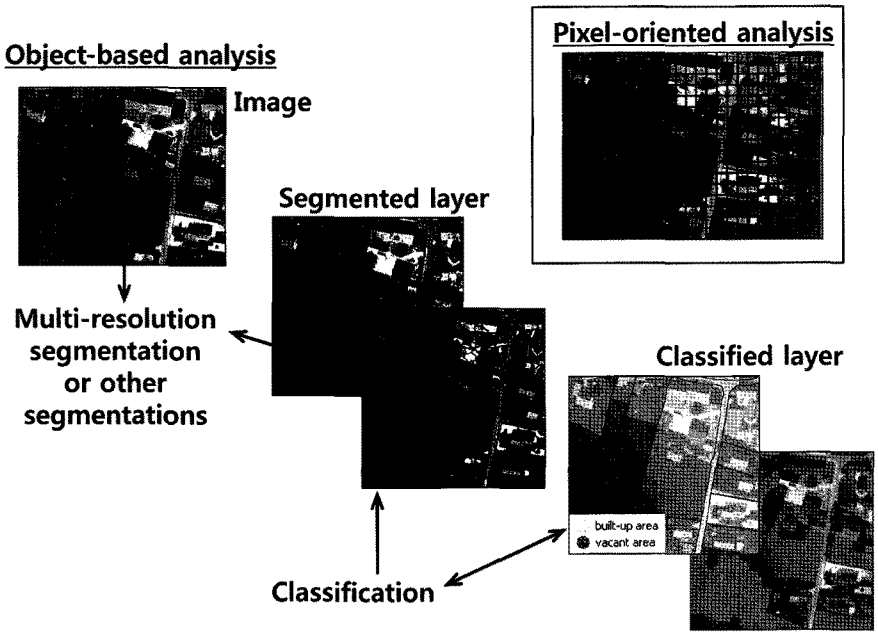

Fig. 1. Fundamental GEOBIA processing steps, modified from Niemeyer (2009).

target image is widely used, although that operation-based segmentation to obtain required objects of the scene based on homogeneity criteria and segmentation using image model for image scene perception by mathematical formulation of the image are applicable. In case of eCognition software, several segmentation parameters are used: scale, color, shape, compactness, smoothness, and weighting factors such as PAN and NDE.

3. A PRELIMINARY IMPLEMENTATION

The implementation in this study totally used open sources. This study aims at a prototype implementation for further specific applications handling actual data in a target region. Moreover, this approach is for a simple but practical design of geo-object, by directly using GIS layers. Fig. 2 and 3 are for the explanation of basic methodology or strategy, and Figs. 5, 6 and 7 are implemented cases including integrated user interfaces.

Fig. 2 summarizes the open sources list and corresponding work flow. Main features for GEOBIA and other Image processing are from Orfeo Toolbox (OTB). OTB 3.8 is the most update version as of this study, and this is a full-featured open source for high resolution images including pre-processing and corrections, feature extraction, image classification, and change detection, with a client application named Monteverdi (Christophe *et al.*, 2008; Christophe and Inglada, 2009; Inglada and Christophe, 2010; OTB development team, 2010). While, Kang and Lee (2010) developed a prototype of OTB application system linked to spatial database for the general remote sensing processing and analysis. As for the unique and previous OBIA implementation using OTB in Michel *et al.* (2010), it is suggested that some object attributes can be utilized such as geometric ones of surface, elongation, or Flusser moments, statistical ones of mean, variance, skewness, kurtosis, and radiometric ones of NDVI.

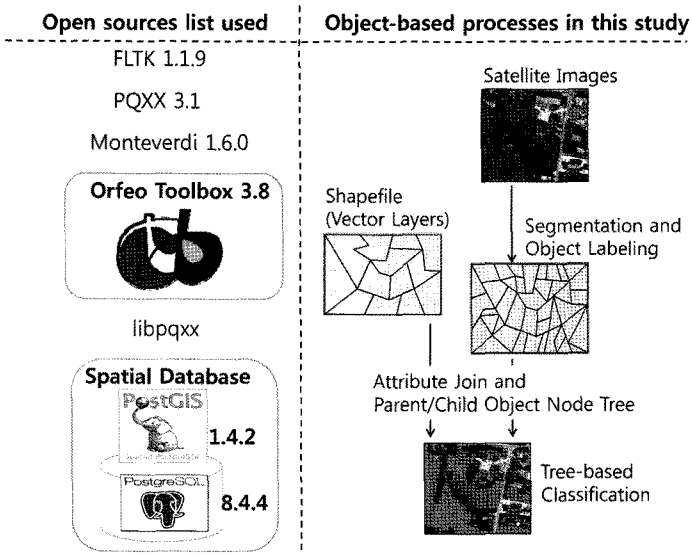

Fig. 2. Work flow for object-based processing and open sources used in this study.

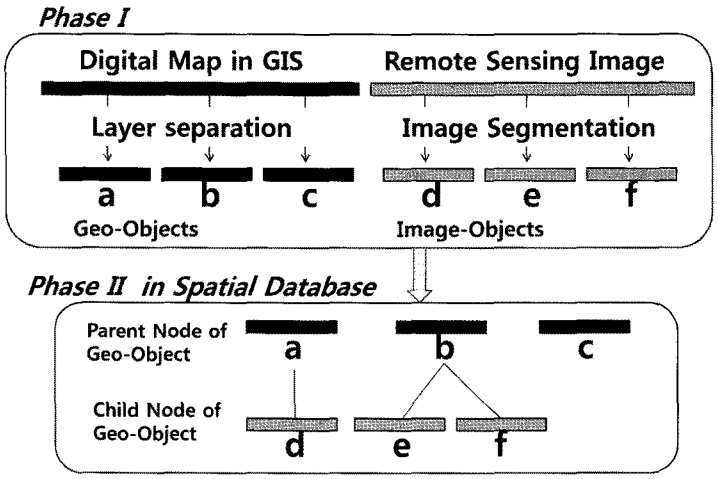

Fig. 3. Strategy for tree-based classification by geo-objects (a, b and c) and image-objects (d, e and f): Phase I to Phase II.

For graphical user interface within an integrated system of GEOBIA, FLTK and PQXX are used in this study. Spatial database for geo-object is also open source database management system. The OTB processing sources and a spatial database of PostgreSQL/PostGIS are linked, using libpqxx module.

Object-based processes proposed in this study in Fig. 2 are as follows. After importing and registration geo-referenced satellite image into implemented system, segmentation and object-labelling is carried out. GIS layers in the digital map related to analysis targets or application purpose also registered into this system. Attributes contained in vector layers and labelled objects of segmented images are registered into spatial database system, and attribute join is performed as automatic or semi-automatic mode with respect to vector layer and segmented images,

respectively. In this joining step, relation between parent or child nodes is established for further classification work. Actually, the classification process is the most distinguished point from other GEOBIA system including eCognition software. It is based on tree classification taking parent nodes and child nodes. This process includes node addition, insertion, and deletion of nodes for geo-objects. Using spatial database, node-based tree construction in the form of hierarchical network and its classification are the other different point, compared to traditional OBIA, because most GEOBIA applications is based on file system. In this study, an image-object and a geo-object are separately manipulated, so that geo-objects are processed in spatial database system. As well, this approach does not need image-based classification in Fig. 1, as the main step. Tree-based classification is processed by attribute join with GIS vector layers in database.

Fig. 3 illustrate basic scheme for tree-based classification in this study. Geo-objects are from GIS layers, and image-objects from a given remote sensing image data. After layer separation and image segmentation processes, all objects are stored as nodes in spatial database. In this system, the criteria are that geo-objects corresponds parent nodes and segmented objects do child nodes. But vice-versa case also is possible in the actual applications.

While, OTB-based GEOBIA procedures and functions concerned are shown in Fig. 4 (A) and (B), respectively, as the reference in OTB development team (2010). The basic functions for OTB are Label_Object_Map, Image_to_Label_to_Map, and Shape_Attribute_Computation. At present, OTB-based GEOBIA is under developing, and some procedures are not directly supported or finalized yet. General users may have difficulties to perform GEOBIA application. As well, object formulization in OTB-based GEOBIA is somewhat different from that of eCognition software.

Fig. 5 shows implemented results, and Fig. 5(A) is a user interface within an integration system for segmentation dialog and database dialog for GEOBIA approach. Segmentation menu provides graphic control boxes for setting parameters: spatial radius, range radius, minimum region scale, and scale elements. These parameters are the mean shift algorithm (OTB development team, 2010) for image

(A)

1. Image segmentation
2. Image to LabelObjectMap transformation;
3. Eventual relabeling;
4. Attribute computation for the regions using the image before segmentation:
   (a) Shape attributes;
   (b) Statistics attributes;
   (c) Attributes for radiometry, textures, etc.
5. Object filtering
   (a) Remove/select objects under a condition (area less than X, NDVI higher than X, etc.)
   (b) Keep N objects;
6. LabelObjectMap to image transformation

(B)

Command/Functions	Parameters
ImageToLabelToImage	input output inPretty outPretty conn fg bg
ShapeAttributeComputation	input outputcentroidlist
RadiometricAttributesLabelMapFilterExample	reffname outfname .....

Fig. 4. (A) Suggested procedure for OTB-based OBIA by OTB development team (2010), (B) Supporting functions for OBIA application in open source of OTB.

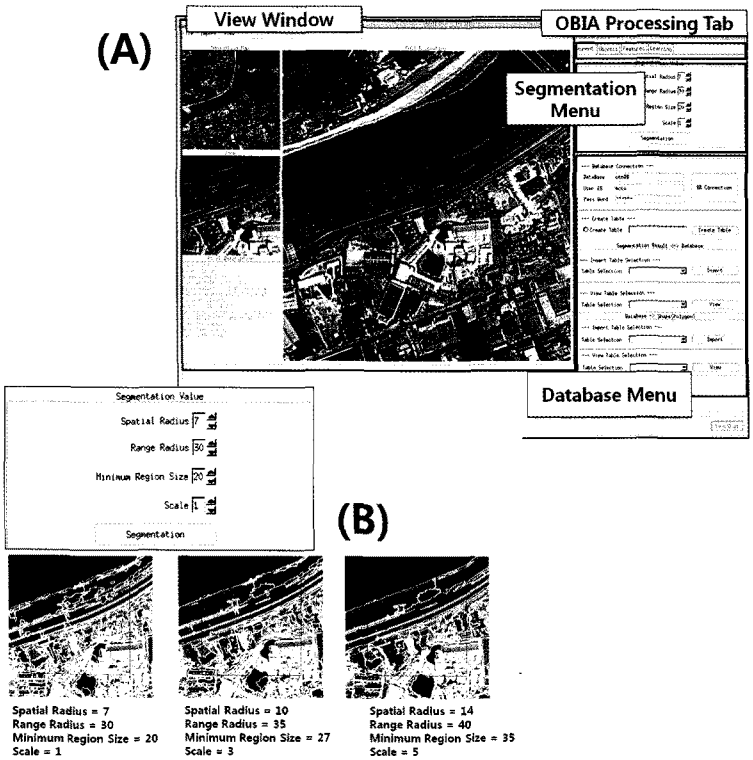

Fig. 5. (A) User interface within an integration GEOBIA system implemented in this study, (B) Segmentation processing interface and parameters for the mean shift algorithm.

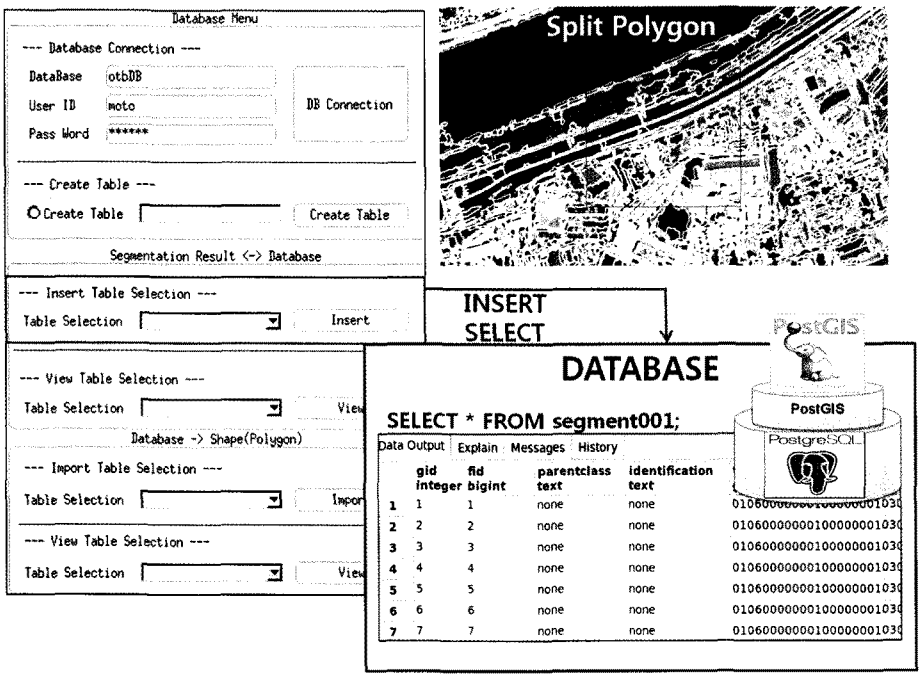

Fig. 6. Integrated interface of spatial database: connect, create, insert, view, or import table.

segmentation process. Fig. 5(B) is some processing results by different parameters of image segmentation algorithm in this implementation.

Fig. 6 shows several dialog boxes related to database transaction for GIS vector layer registration: database connection, create table, insert table, import table, and view table for the whole layers and split polygon layers. In this figure, a part of region is split from large area, and database insertion and selection for vector layer for this part can be processed. While, database schema in this preliminary system is simple structure composed of feature ID, parent node, or identification node, but more detailed modelling can be added in the case of actual applications.

Fig. 7 is for image labelling and tree classification with parent and child nodes. Fig. 7(A) is for the registration of labelled image and object class generation. Fig. 7(B) and Fig. 7(C) are overlay vector map on segmented image and node creation for geo-object tree, respectively. In this implementation, pan-sharpened image composited from multi-spectral satellite images is used, and air-borne photo also can be substituted. If multi-spectral images are applied, image-based classification is necessary, in the same process of eCognition software. This functionality is not supported in this preliminary product, yet. It is planned to be add in the next extension of this GEOBIA system.

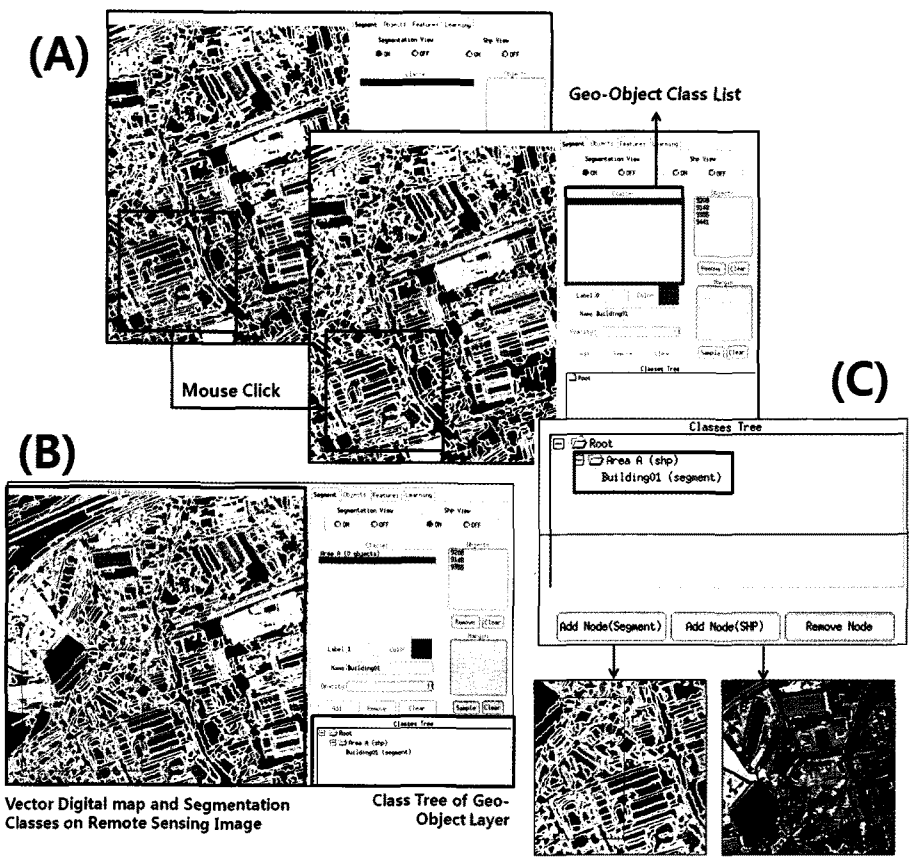

Fig. 7. (A) Registration of labelled image and object class generation, (B) Overlay vector map on segmentation image, (C) Node creation for geo-object tree.

4. CONCLUDING REMARKS

Normally, most applications based on GEOBIA need time-consuming and complicated processes to achieve application goal. Despite, GEOBIA approaches are increasing in most remote sensing applications because they provide more accurate and detailed results, compared to pixel-based approaches. Thus, it is natural that cost-effective or low cost GEOBIA are necessary.

In this study, the applicability of geo-spatial processing open source to GEOBIA is examined by a preliminary implementation of GEOBIA system running an integrated and user-oriented environment. Because full supporting open sources for GEOBIA do not exist in the current stage, several kinds of open sources are used in an integrated GEOBIA, and they have some distinguished points, compared to eCognition software.

The main features in this implementation are summarized: segmentation by the mean shift algorithm, object-labelling for segmented results, attribute join of GIS vector layers and image-objects, and tree-based classification of parent and child nodes in the semi-automatic mode. If a user wants to use GEOBIA linked to GIS application for artificial structures or well-defined features, this approach can be easily adopted, because geo-object concept is closer to data modelling in spatial database, than to image-based operation. In handling nature-based features in environmental problems, earth resources, forest applications or other kinds of feasible applications, GEOBIA functionalities provided by eCognition software is better than this approach. This implementation is not finalized product, so that there are many things to do. But it is thought that applicability of open source for GEOBIA is affirmatively prospective, judging from implementation experiences in this study.

As for the further works of this study, other segmentation algorithms for more deliberated formulization of geo-object classes should be implemented. Practically, geometric, statistical or radiometric attributes can be considered. And case studies on actual applications with the purposes of urban mapping or change detection are possible, although it is not presented at detailed level in this study. Also, image-based classification with segmented image sets and other variables will be provided for remote sensing communities. Automatic object tree construction process is needed for GIS users. More, a comparative study with respect to performance and functional features with other proprietary GEOBIA software is needed.

As the matter of the fact, GEOBIA itself is still maturing scheme or methodology; various types of implementation approaches are possible. It is thought that GEOBIA implementation using open sources helps to develop new applications directly linked to GIS data sets and to solve some limitations or problems of pixel-based analysis and interpretation taking types of remote sensing sensors.

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