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以物件為基礎的方法整合地理資訊及遙測影像做土地使用特徵擷取與分類

An Object-Based Method to Integrate Remote Sensing and Geographical Information for Advanced Feature Extraction

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摘　要

本文在呈現利用以物件爲基礎的方法整合地理資訊及遙測影像資料做土地使用特徵擷取與分類的研究。本研究的動機在於探討如何整合多樣性的空間資料，並轉化爲物件化的知識，作爲土地使用特徵擷取與分類的基礎。在本研究中所提出之以物件爲基礎分析單元並結合物件內含知識推論的分析方法，比傳統的以像元或網格區域爲基礎分析單元的分析方法，更接近真實世界認知與分類方法，並可獲得較好的資訊擷取與分類結果。

本研究依相關分析與設計，建構了實際應用的雛型系統–OMIRGS。並利用兩組不同年份的空間資料做案例分析。由案例分析的結果顯示，利用 OMIRGS 針對本研究中所設定的九種土地使用特徵擷取及分類的結果，分別有 93% 及 94% 的分類準確度。相對於傳統的單純以 SMAP 關聯性影像分類方法所的到的結果，其結果有顯著的改進。而由相關結果顯示，利用本研究所設計，以物件爲基礎分析單元並結合物件內含知識推論的分析方法，能擷取到僅利用傳統的遙測影像分類分析方法所無法得到的分類結果。

關鍵字：地理資訊系統、遙測、影像分析、特徵擷取、土地使用分類

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Abstract

This paper presents an object-based method to integrate remote sensing and geographical information systems for advanced feature extraction. The research was motivated by the need to integrate spatial data for feature extraction and the hypothesis that an object-based approach would lead to improved results compared to pixel and kernel-based approaches. A prototype system – OMIRGS, had been designed and implemented in this research.

A case study for object land use classification and change detection within an urban-rural area has been carried out. Promising results have been obtained from the case study. The 1988 and 1990 land use maps of the case study area, with 9 classes of land use features; have been generated with an accuracy of 93% and 94%. Significant improvements have been obtained comparing the results with those generated using the SMAP contextual image classification method alone. This research concludes that the method proposed in this research can be used to extract the features, which are very difficult to derive using conventional techniques and remotely sensed data alone. The work contributes to the prioritized research area of the integration of remote sensing and geographic information systems for advanced feature extraction.

Keywords: Geographical Information System, Remote Sensing, Image Analysis, Feature Extraction, Land use Classification.

Introduction

The primary objective of this research is to explore the full potential of using an object-based approach to integrate spatial data and knowledge for extracting the features which are very difficult to derive using conventional techniques and remotely sensed data alone. The secondary objective of this research is to simulate planners' inference processes and exploit the application of object-based spectral, spatial and feature knowledge derived from spatial data and domain knowledge for advanced feature extraction.

In response to the motivation and objectives, this paper presents an object-based approach to the integration of spatial data and knowledge to aid feature extraction from remotely sensed data. The research was motivated by the need to integrate spatial data for feature extraction and the hypothesis that an object-based approach would lead to improved results compared to pixel and kernel-based approaches. The expected benefits of the object-based approach is the ability to represent object-based spectral, spatial and features knowledge derived from spatial data and domain knowledge. The details of motivation will be described according to the following topics:

1. Integration of spatial data for advanced feature extraction

The requirement to integrate spatial data from different sources, such as data from remote sensing (RS) and geographical information systems (GIS), for the potential of extracting features from RS data to update the object information in a GIS has been growing in recent years [4, 15, 5, 6, 7]. Comprehensive research into the integration of RS data with GIS was proposed by the NCGIA (National Centre for Geographic Information Analysis) in the early 1990s as part of their initiative 12 (NCGIA I-12), "Integration of Remote Sensing and Geographic Information System" [5]. Several research areas with subtopics were emphasized in the report of NCGIA I-12 in 1991 [5]. These were reviewed and revised by Estes and

Star [7] who proposed a "prioritized research agenda". The advanced feature extraction has been prioritized by Estes and Star as the highest priority research area according to their agenda.

As stated by Estes and Star [7], advanced feature extraction is the topic that received less attention than they thought and does not fit neatly into any of the NCGIA I-12 subgroups. However, this research area should be done in order to explore the full potential of using integrated RS and GIS [7].

2. Object-based approach for the integration of spatial data

The problems of per-pixel-based approaches used in conventional methods for the integration of RS and GIS have been discussed by a number of researchers [8, 9, 1, 10]. The heterogeneous results and the need for heavy post-classification tasks characterize the deficiency of this approach. Furthermore, this approach is not suitable for extracting features, such as urban land use, whose direct relationship with spectral characteristics of RS data can not be clearly defined. Research shows that object-based approaches, based on pre-defined object areas for integrating RS and GIS provide a better means for feature extraction from RS data [1, 10, 8, 11, 12, 13]. Hence, the object-based approach will be investigated and used in this research for the integration of spatial data.

Although, the benefits of using object-based approaches for integration RS and GIS have been mentioned by a number of researchers [10, 11, 12] , the ambiguous definition of the term "object" used by current researchers may lead to confusion and arguments over the integration and feature extraction results. Meanwhile, some current object-based approaches which use summarized information for each object for the integration usually suffer from the problem of features being over-written [11,12]. Since a pre-defined object area is used in these object-based approaches as the basic processing unit, an object area can only be assigned summarized information. Hence, valuable feature information contained within object areas, which do not have their own pre-defined area may be over-written and summarized by the feature of the pre-defined object areas. For example, newly developed residential sites at urban-rural areas may be summarized by the feature of agricultural land use. Thus, the definition of the term "object" and the problem of features being over-written within pre-defined objects are the other problems which will be investigated in this research.

3. Object-based knowledge for advanced feature extraction

Conventional knowledge-base interpretation of RS data is based on knowledge derived from RS data at the pixel level. The limitations of this pixel-level knowledge has led to the use of kernel-level knowledge which takes account of the contextual information of a pixel [9, 1, 14] for feature extraction. Recent research shows that object-level knowledge, such as the size and shape of objects [11], the relationships between defined objects [1] and the knowledge derived from ancillary data [11], can be used to improve the integration of RS and GIS for feature extraction. However, the problem of these approaches is that it is difficult for them to implement the object-based knowledge derived from the application domain, such as the compositional relationship between land cover classes and land use classes, for feature extraction.

Hence, the awareness of the potential of using object-based knowledge derived from spatial data and domain knowledge for advanced feature extraction leads to the third motivation of this research. The investigation of methods for deriving and organizing the object-based knowledge will be a major part of this research. A method for implementing the domain knowledge for advanced feature extraction will also be developed.

The Objectives

This research will focus on developing an object-based method to integrate spatial data and knowledge for the extraction of features, such as the land use feature within urban-rural areas, which are very difficult to obtain by a conventional integration method.

According to the motivation of this research described above, the objectives of this research are as follows:

(1) The primary objective of this research is to explore the full potential of using the object-based approach to integrate spatial data and knowledge of spatial data and domain knowledge for the purpose of extracting the features which are very difficult to derive using conventional techniques and RS data alone.

(2) The secondary objective is to simulate planners' inference processes and exploit the application of object-based spectral, spatial and feature knowledge generated from spatial data and domain knowledge for advanced feature extraction.

(3) The other objectives of this research include: a) to investigate the definition of the term "object" by considering the characteristics of the object; b) to investigate the problem of features being over-written within pre-defined object areas; c) to explore the object-based method for accuracy assessment.

Definition of Term

This section will define the term "object" as used in this research. First, we need to outline the definitions of spectral and feature classes.

1. Definition of Spectral and Feature Classes

(1) Spectral Classes: Spectral classes are defined as those classes whose candidate information holds direct and unambiguous relationships with the characterization of the classes classified from RS image data. Furthermore, this information derived from RS data is a kind of resource-oriented information, which represents the real world situation at the time when RS image data, was taken. Hence, it should exist in its original form and without pre-defined spectral class areas. Usually, the candidate information of spectral classes can be derived from RS image data with reasonable accuracy by using pixel-based pattern recognition approaches or contextual image classification approaches. Land cover classes derived from RS data are examples of spectral classes.

(2) Feature Classes: Feature classes are defined as those classes whose candidate information is artificially assigned according to the functions and activities within pre-defined feature class areas. The information usually holds indirect or complex relationships with the characterization of the classes classified from RS image data. Furthermore, since the information of feature classes is artificially assigned and function-oriented, it usually exists in the form of information summarized over pre-defined areas (e.g. land use information is a kind of summarized information since each polygon of a land use map is assigned a unique land use type). Complicated methods (e.g. image understanding methods which integrate

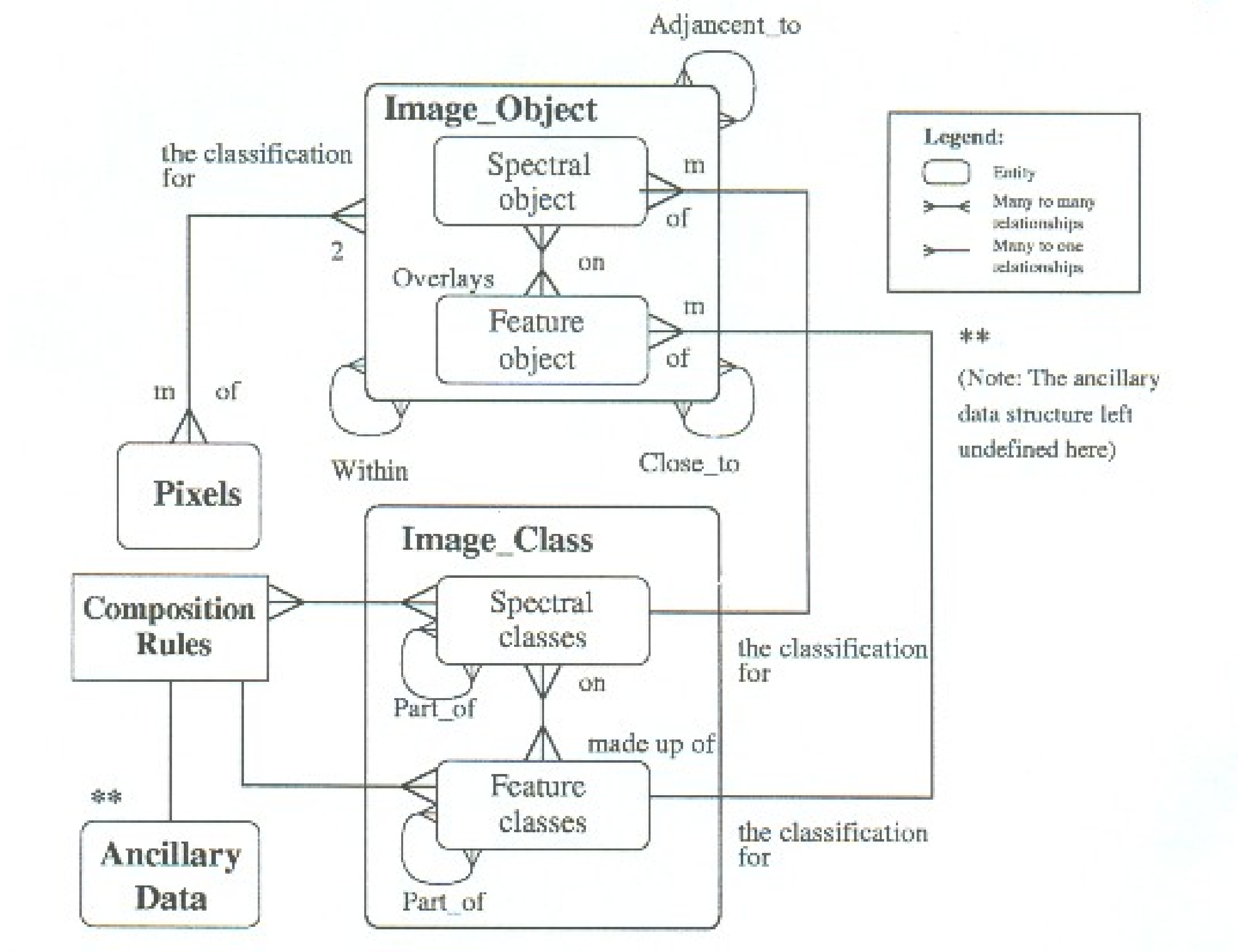


Figure 1 The Relationship between spectral and feature classes using Entity-Relationship Modeling

ancillary data) and extra knowledge (e.g. from spectral classes or GIS) should be used for deriving information of feature classes. Land use classes provide an example of feature classes.

The terminology of the Entity Relationship (E-R) Modeling [2, 3] has been used to construct a diagram for showing the relationships between spectral and feature classes in Figure 1. As shown in the diagram, feature classes are composed of spectral classes based on some composition rules. For example, land use classes are formed by spatial assemblage and arrangement of land cover data [1]. The composition rules are derived from the knowledge of the spectral classes, ancillary data and the knowledge of application domains.

2. Definition of "object"

As mentioned motivation, an ambiguous definition of the term ''object'' is likely to cause confusion and arguments as to the suitability of an object-based method and its results. Hence, a clear definition of the term "object" should be given to avoid any such confusion or arguments.

Using the definition of feature class defined in former section, the term "object" used in this research is defined as follows:

(1) In Raster Format: With respect to feature classes, an object is defined as an identified contiguous region with a uniform feature class. With respect to

spectral classes, an object is defined as an identified contiguous region with a uniform spectral class within a pre-defined feature class area.

(2) In Vector Format: With respect to feature classes, an object is defined as an identified polygon with an assigned feature class. With respect to spectral classes, an object is defined as an identified polygon with a uniform spectral class within a pre-defined feature class polygon.

According to the definition given above, there are two kinds of object: feature objects and spectral objects; used in this research. The relationships between these two objects can be seen in Figure 1. Since the main purpose of this research is to derive feature class information, the limitation of the imposed boundary on the spectral object is necessary to avoid any confusion and ambiguity between feature and spectral objects.

Conceptual Design of the System Prototype - OMIRGS

This section provides an overview of OMIRGS by describing the structure of OMIRGS and the processing phases designed for OMIRGS.

1. Structure of OMIRGS

The main objective of OMIRGS is to use the integrated spectral, spatial and feature knowledge which is generated from RS, GIS, ancillary data and domain knowledge for feature extraction. Hence, the methods for knowledge derivation, analysis, evaluation, integration and inference will form the most important parts of the methodology of the object-based approach proposed here.

Conventional approaches for the integration of RS and GIS have employed three processing phases: data pre-processing, information extraction and data post-processing. However, our object-based approach for knowledge integration uses six phases as shown in Figure 2.

In general, the data pre-processing and accuracy assessment phase used in this method are similar to those in conventional approaches for the integration of RS and GIS. However, since the object-based concepts have been introduced and used in this method, an object reference map was created in data pre-processing phase. Furthermore, object-based techniques were developed in the accuracy assessment phase for generating an object-based accuracy index map to show the spatial distribution of the accuracy of objects and the approximate location of errors.

In conventional approaches, the integration takes place only in the feature extraction phase, i.e. when extracting feature class information. By contrast, our approach is concerned with integration of RS and GIS knowledge at each phase in the process. The process of feature extraction is itself divided into four phases namely: the data and domain knowledge analysis, knowledge generation, knowledge evaluation and integration, and feature extraction. This leads to greater flexibility of this method. In addition, instead of using image classification techniques for information extraction, evidential reasoning can easily be implemented in this method. The advantages of integration of evidence derived from a number of phases can be seen since: 1) the reliance of the interpretation on a single property of a feature type is reduced; 2) a variety of properties can also be considered.

2. Processing Phases of OMIRGS

As shown in Figure 2, six processing phases have been designed for the implementation of OMIRGS. The main purpose of these phases is described in this section.

(1) Data Pre-processing Phase: This phase refers to those operations that are preliminary to the main data analysis. The main purpose of this phase is to improve the quality of the data that will be integrated for extracting features from the integration of RS and GIS. Furthermore, if needed, ancillary data for helping feature extraction should be created in this phase, for example, the creation of training data set from GIS data for supervised image classification of RS data.

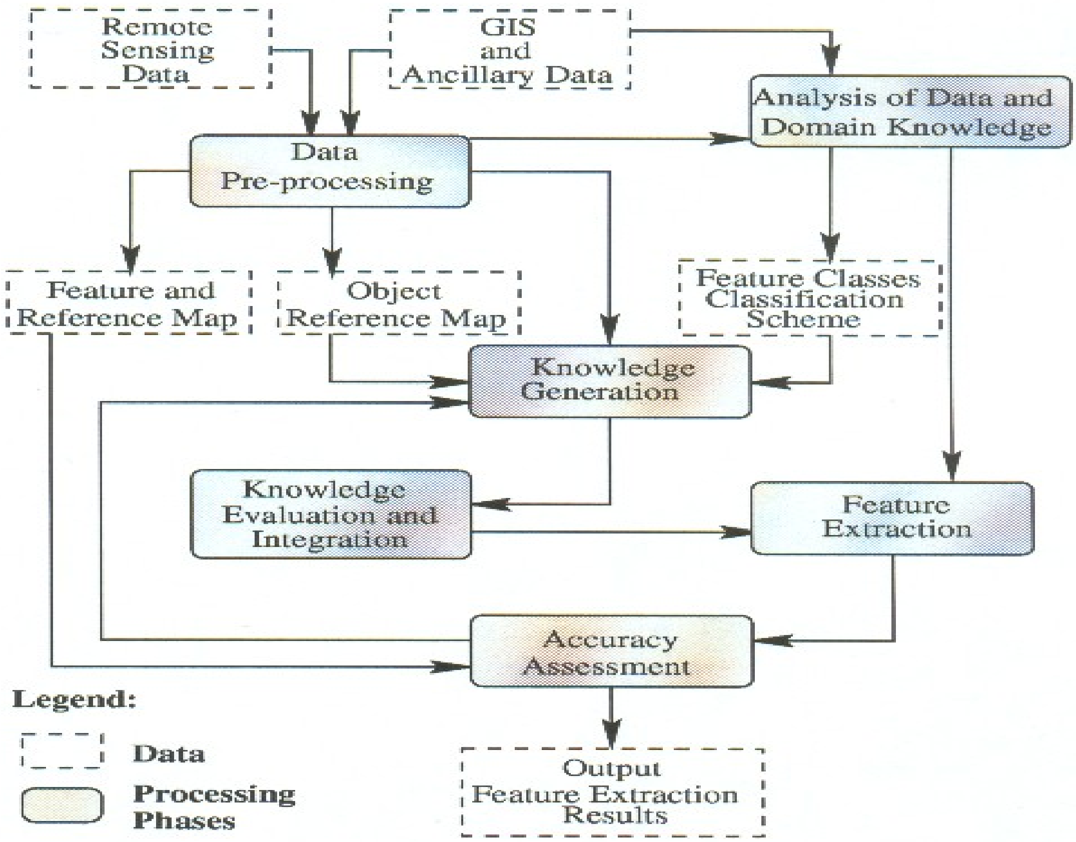


Figure 2 The conceptual diagram of the phases in the methodology of OMIRGS

(2) **Data and Domain Knowledge Analysis Phase:** The main purpose of this phase is to derive knowledge from the application domains and the RS and GIS data used in the integration. This knowledge can be used to reduce the data volume for further processing. For example, the knowledge derived from the analysis of multi-spectral RS data can be used to select sufficient channels for feature extraction that may be fewer than the source data. The derived knowledge can also be used in the knowledge generation phase. For example, the land cover classification scheme derived knowledge can be used in the image classification method for generating knowledge of object-based land cover. Furthermore, it can also be presented as rules and applied in the knowledge inference phase for feature extraction.

(3) **Knowledge Generation Phase:** The purpose of this phase is to generate object-based knowledge

from the integrated RS and GIS. Three kinds of knowledge: spectral, spatial and feature knowledge, will be generated in this research.

(4) Knowledge Evaluation and Integration Phase: The purpose of this processing phase is to evaluate the knowledge generated from the previous phase by investigating its suitability and sensitivity before it can be chosen for extracting feature information. Another purpose of this phase is to integrate the chosen knowledge in a database for knowledge inference.

(5) Feature Extraction Phase: The purpose of this processing phase is to extract feature information from the integrated knowledge using evidential reasoning processes.

(6) Accuracy Assessment Phase: The purpose of this phase is to assess the accuracy of the feature extraction results by comparing the results with reference data. Also it can be used as a quality control phase for the object-based approach.

System Architecture Design of OMIRGS and Case Studies

1. OMIRGS System Architecture Design

System architecture has been built for the implementation of OMIRGS. It is divided into three parts:

(1) Processing Module: Three processing modules namely data processing, knowledge generation and evaluation and feature extraction and assessment have been created in this prototype.

(2) Processing Kernel: The processing kernel of this prototype is mainly based on the GRASS4.1 GIS software package (GRASS) for providing user interface and processing functions. The SQL query language has also been used in the processing kernel to implement evidential reasoning for feature extraction.

(3) Rule base/Database: A rule base has been created for containing rule structures for feature extraction. A relational database system, Ingres, has been used for the integration of the derived spectral, spatial and feature knowledge.

The design of this system architecture is based on the requirement analysis for each processing phase of OMIRGS and the methods which have been outlined for use in each phase. The diagram in figure 3 shows the architecture using the processing modules, the processing kernel, the rule-base/database and the relationships between these components.

2. Knowledge Generation Module

The knowledge generation methods designed in this research are shown in figure 4. Mainly there are two types of knowledge used in this research. The first is the feature classification scheme generated in the phase of analysis of data and domain knowledge. It is used in the significance analysis for selecting texture measurements for the integration. The second type of knowledge is the experts' knowledge which contains subjective judgments and is used in the evaluation and selection of spectral class map for the integration.

As we can see that there are three categories of object-based knowledge, the spectral, spatial, and feature knowledge, are proposed. This knowledge is generated and objectized so that it can be integrated at the database level for feature extraction using an evidential reasoning method.

The following steps have been design for the objectization of the knowledge to be integrated:

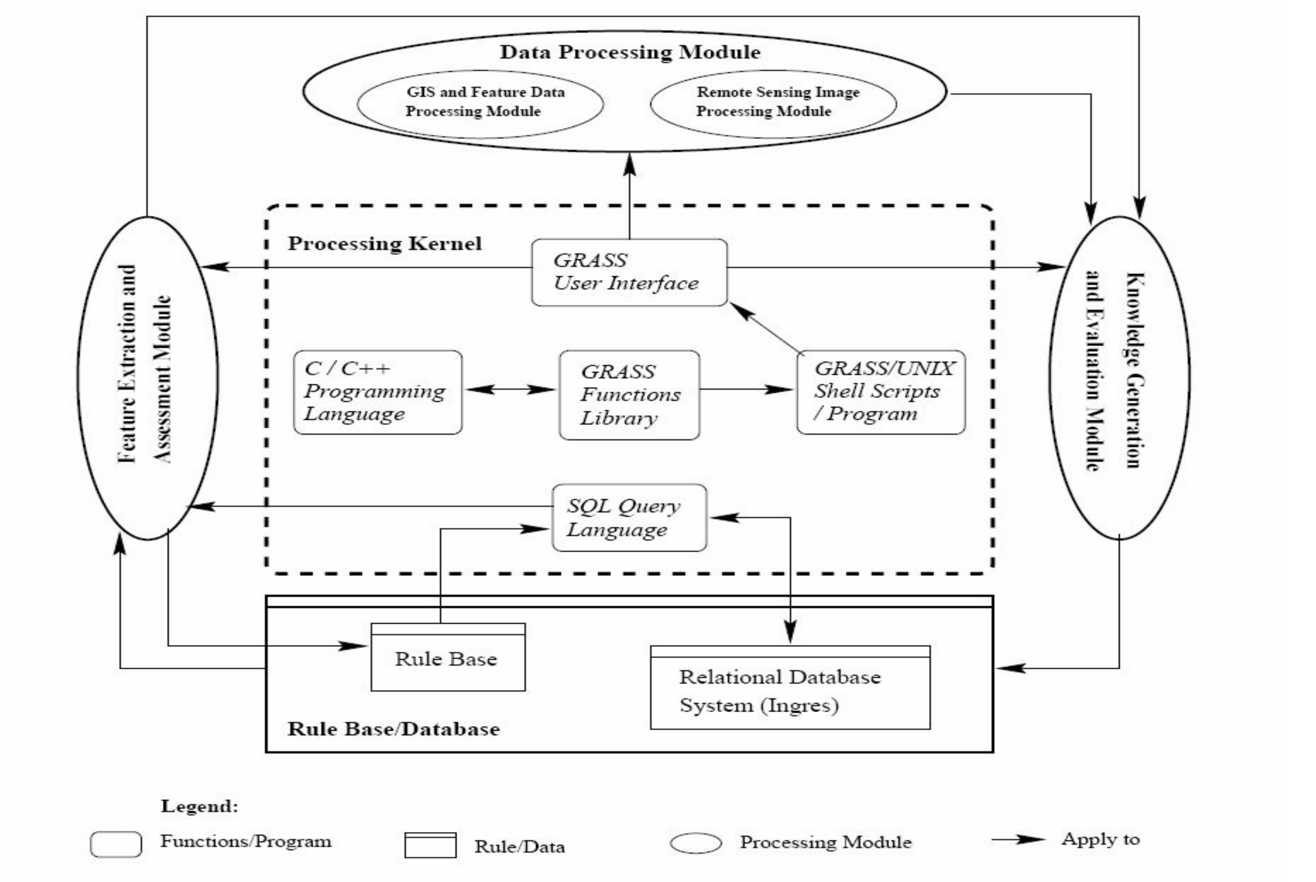


Figure 3 The system architecture diagram of OMIRGS

Step 1: Selected an object area from the object reference map and store its object identification number in the database.

Step 2: Refer to the boundaries of the selected object area, extract the corresponding object area from the selected spectral and feature maps.

Step 3: Outline the values of the selected texture measurements of the selected object and store the values in the database.

Step 4: Outline the types of spectral and feature classes composed within the selected object area and calculate their associated compositional values.

Step 5: Outline the first three significant types of spectral and feature classes composed within the selected object area according to the compositional values generated in the fourth step.

Step 6: Store the first three significant types of spectral and feature classes outlined in the fifth step and their compositional probability values in to database.

Step 7: Repeat the above procedures until all object area of the object reference map have been selected and their spectral and feature knowledge has been outlined, calculated and stored.

For storing the objectized spectral, spatial and feature knowledge generated, a database table was defined as shown in table 1.

3. Feature Extraction and Assessment Module

There are two processing steps used here. The first step is used for the derivation of object-based rules and composition of the rule base for evidential reasoning. The

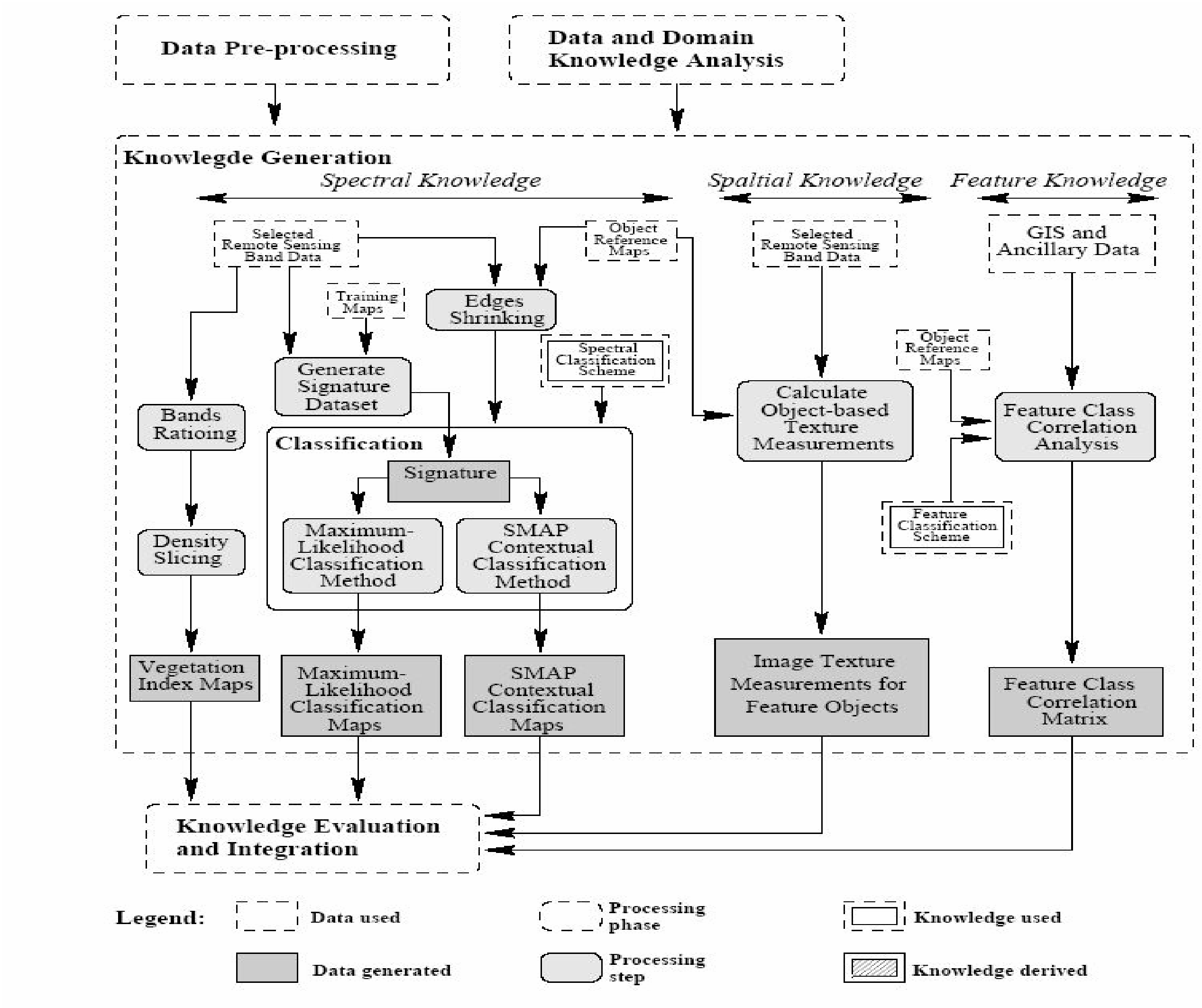


Figure 4 Methodology designed for the knowledge generation of OMIRGS

second step is the evidential reasoning for feature extraction. The methodology designed for feature extraction in OMIRGS is shown in figure 5.

The object-based rules used for feature extraction are specific to the particular feature class to record the degree of class membership determined by the objectized knowledge integrated in the database. Each appearance of feature class requires a separate rule structure for evidential reasoning. Figure 6 shows and example rule structure for extraction the land use feature class of residential sites. Subjective analysis on the selected maps and texture measurements by referring to the experts' knowledge, domain structure, and feature classification scheme is used here to derive object-based rules for evidential reasoning. Meanwhile, a manual method is used to construct the rule base.

Table 1 Fields and data type of the table defined for knowledge integration

	Source of Knowledge	Fields for Storing Objectised Knowledge	Data Type (class)	(Probability)
	Object Reference Map	Object Identification Number	Integer (6)	
Spectral Knowledge	Level I Land Cover Map	First Significant Class Second Significant Class Third Significant Class	Text (4)	Real (6)
Spectral Knowledge	Level II Land Cover	First Significant Class Second Significant Class Third Significant Class	Text (4)	Real (6)
Feature Knowledge	Contour Feature Class Map	First Significant Class Second Significant Class Third Significant Class	Text (4)	Real (6)
Feature Knowledge	Slope Feature Class Map	First Significant Class Second Significant Class Third Significant Class	Text (4)	Real (6)
Spatial Knowledge	Texture Measurements	Angular Second Moment		Real (6)
Spatial Knowledge	Texture Measurements	Entropy		Real (6)
Spatial Knowledge	Texture Measurements	Contrast		Real (6)
	Feature Extraction Result	Assigned Feature Class	Text (4)	

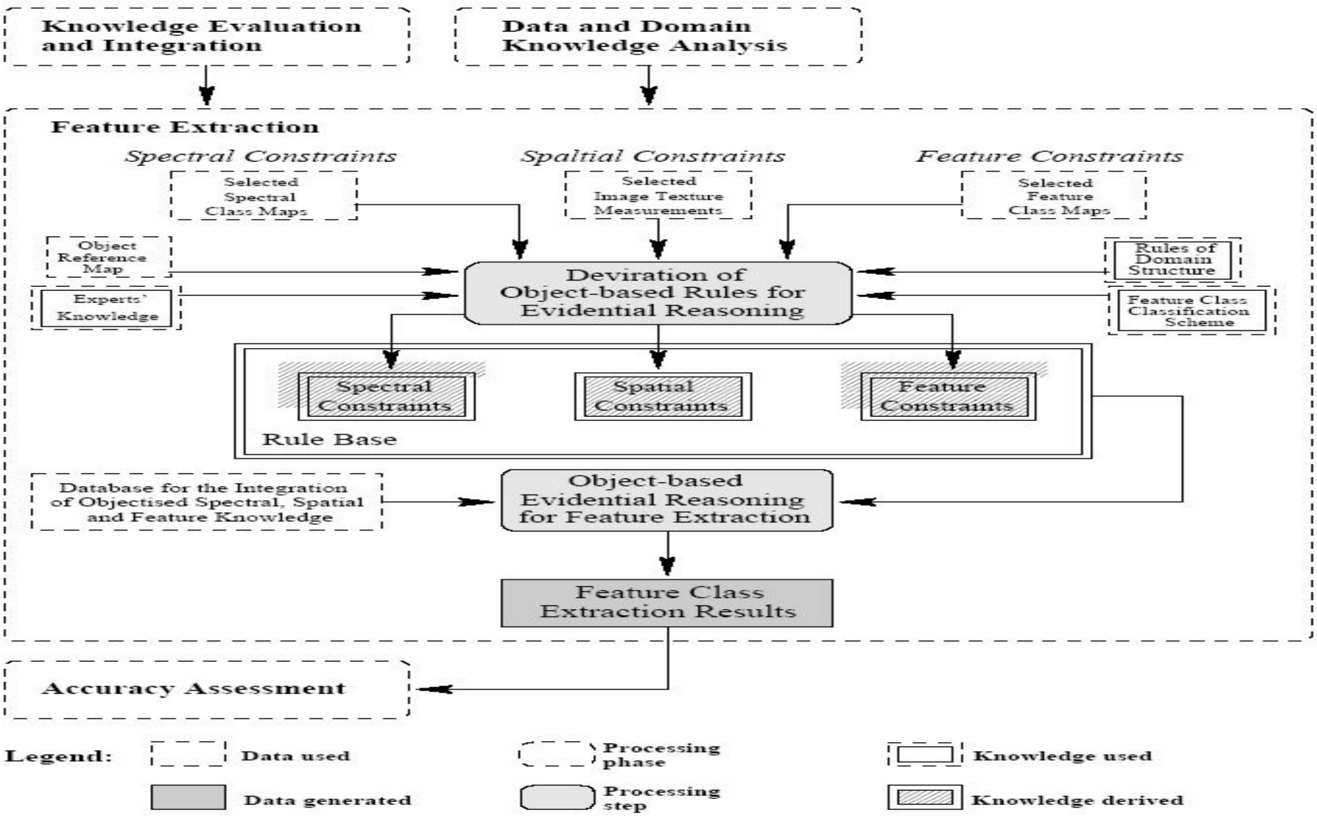


Figure 5 Diagram of methodology designed for feature extraction in OMIRGS

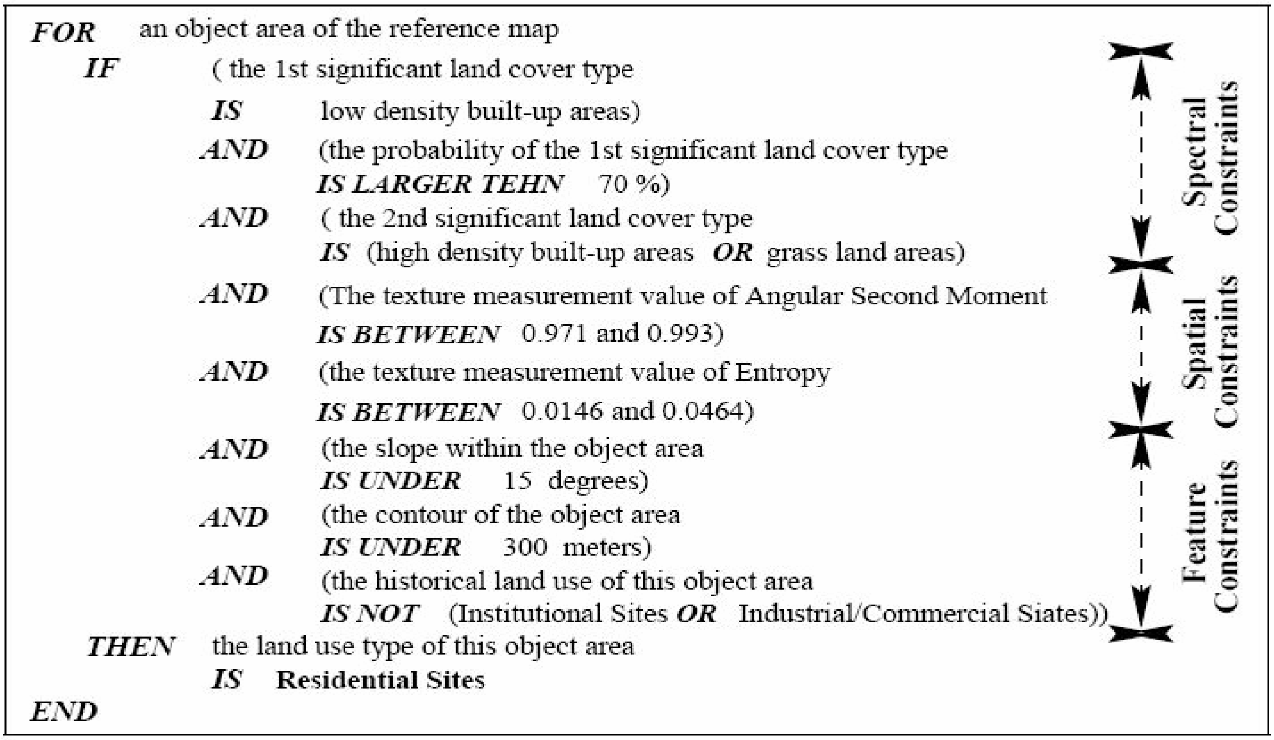


Figure 6 An example rule structure for extracting land use feature class of residential sites.IRGS

An object-based evidential reasoning method was designed here for feature extraction. The aim of this method is not to create a comprehensive system to extract all the feature classes simultaneously but rather to extract feature classes separately. Hence, it relies on experts' knowledge for configuration using a trial-and-error method, but subsequently enables non-expert to make use of the knowledge that has been provided. The trial-and-error method used here is mainly to adjust the rule structure provided by the rule base, if necessary.

Since the integration of knowledge is the main concern of OMIRGS, the object-based evidential reasoning method used here decides the feature class of each object based on the evidence provided by the objectized knowledge which was been integrated at a database level. In order to combine evidence, rules structures which comprised spectral, spatial and feature constraints (figure 6) and provided by the rule base are used. The SQL query language is used here for the implementation of the rule structure for evidential reasoning and feature extraction.

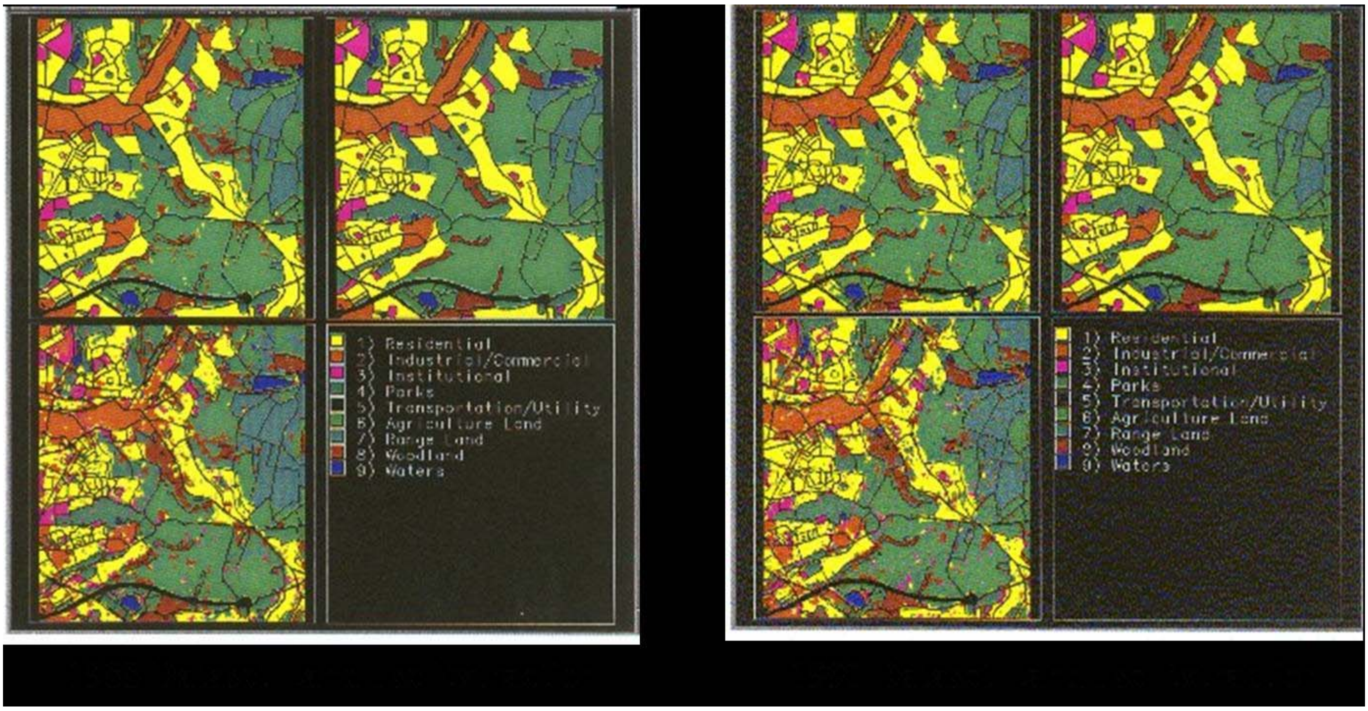
Once the feature class of an object is decided, the type of the feature class is then used to update the values in the column of "assigned feature class" which was predefined for each object in the database for integrating objectized knowledge. The updated values are then linked with their corresponding object identification numbers to generate the feature extraction map by reclassification the original feature map or the object reference map with object-based boundaries. The extracted feature map is then used for accuracy assessment.

4. Case Studies Results and Assessment

A case study has been carried out using the system prototype of OMIRGS for object land use classification and change detection within an urban-rural area. The Tameside District, an urban-rural area in Northwest England, which is located between the Manchester

Metropolitan District and the Peak District, has been chosen as the case study area. The 1988 and 1990's datasets of this area have been collected and compiled for the case study. The dataset included: Landsat TM data, Ordnance Survey (OS) Landline 93+ sample digital map, OS Landform Panorama digital height data and OS published map.

Promising results have been obtained from this case study. The 1988 and 1990's land use maps of this case study area which included 9 land use classes: residential sites, industrial/commercial sites, institutional sites, park sites, transportation and utility sites, agricultural land, range land, forest land and water; have been generated (as shown in Figure 7).



Upper left: Final feature extraction results by OMIRGS.

Upper right: Simulated reference land use map.

Lower left: Land use map generated by contextual supervised classification method.

Lower right: The Legend.

Figure 7 Case Study Result (left: 1988 Dataset Land use Extraction; Right: 1990 Dataset Land use Extraction)

Accuracy assessment on the generated land use maps has been done by comparing the generated maps with the base land use maps, which have been generated by referring to OS published maps and the information extracted from the results of visual interpretation of the Landsat TM data. The assessment results show that 93% and 94% accuracy has been achieved in 1988 and 1990's land use maps. The accuracy assessment result is shown in table 2. Significant improvements have been obtained compared to the results with the results generated using the SMAP contextual image classification method alone. An object-based accuracy assessment method has also been used to show the accuracy of each object area and the spatial distribution of accuracy. The case study results also show that land use changes from agricultural land in 1988 to a mixture of residential and park site in 1990 have been detected.

Table 2 Accuracy Assessment Results

Land Use Types (Year / Methods)	1988 Land Use Maps						1990 Land Use Maps					
	SMAP		1st Pass		Final		SMAP		1st Pass		Final	
	Com (%)	Omi (%)	Com (%)	Omi (%)	Com (%)	Omi (%)	Com (%)	Omi (%)	Com (%)	Omi (%)	Com (%)	Omi (%)
Residential	66.18	81.98	98.46	95.14	99.69	93.52	72.76	62.46	95.70	99.08	98.79	92.18
Industrial	67.93	61.58	99.76	100.0	99.76	99.98	68.04	60.92	99.75	97.28	99.76	99.80
Institutional	62.01	36.08	100.0	100.0	87.71	100.0	53.19	32.01	100.0	100.0	85.01	100.0
Park	62.58	42.91	99.84	99.99	98.48	99.52	60.00	41.96	99.84	99.99	98.49	99.48
Transportation/ Utilities	47.04	38.94	99.98	79.05	94.11	99.94	42.37	42.99	99.15	78.83	94.11	90.86
Agricultural	57.17	84.78	95.51	97.75	86.13	96.81	57.57	85.92	99.64	94.47	88.53	96.52
Range Land	91.23	41.27	100.0	91.70	99.01	100.0	87.89	41.74	100.0	100.0	98.90	100.0
Forest Land	68.42	34.10	72.45	99.63	71.71	42.19	66.22	39.75	77.84	99.30	74.13	53.69
Waters	82.18	76.46	89.54	100.0	94.18	100.0	80.45	68.13	90.91	100.0	94.04	100.0
Overall Accuracy (%)	63.69		96.31		92.94		64.99		96.81		93.63	
Kappa Value (%)	54.75		95.10		90.66		55.98		95.74		91.52	

Note: Com: Commission Accuracy; Omi: Omission Accuracy

Conclusions

The primary contribution of this work is to tackle the integration from a knowledge perspective for the construction of an object-based method to integrate spatial RS and GIS for advanced feature extraction (OMIRGS). OMIRGS contains the methodology which can be used to analyze, generate, evaluate and integrate object-based spectral, spatial and feature knowledge derived from spatial data and domain knowledge for advanced feature extraction. It also contains an evidential reasoning process using the rules and evidence derived from the integrated knowledge for feature extraction. A method has also been proposed to generate object-based accuracy index maps to show the spatial distribution of accuracy and the approximate location of the errors occurred in feature extraction results.

A case study has been carried out using the 1988 and 1990's datasets collected and compiled for an area within an urban-rural fringe region. Promising results have been obtained by this case study which show that 9 classes of land use within the case study area can be extracted with 93\% and 94\% accuracy for 1988 and 1990's land use map. OMIRGS also leads to significant improvements in the accuracy over the results generated using the SMAP contextual image classification method alone. The results also show that an object area has been identified as having changed from agricultural land in 1988 to a mixture of residential and park site in 1990. The change detection result has been validated by field survey.

The case study results show that the features which are very difficult to derive using conventional techniques and RS data alone can be extracted using OMIRGS prototype. They demonstrate the potential of using object-based approach to integrate spatial data and knowledge for advanced feature extraction. They also support our hypothesis regarding the object-based approach and suggest that development of an integrated object-oriented architecture would be a worthwhile project.

An evidential reasoning process to simulate a planner's inference processes and exploit the application of the object-based spectral, spatial and feature knowledge has been used in this research for advanced feature extraction. The main characteristic of inference processes used by planners is to determine the features of a pre-defined area based on the knowledge and evidence derived within the area as well as the constraints imposed on it. In the same way as the planners' inference processes are based on pre-defined areas, the evidential reasoning process used in the OMIRGS prototype for extracting features is based on an object reference map with pre-defined object areas. The area knowledge and evidence used in planner’s inference processes is equivalent to the object-based knowledge and evidence derived from the integrated knowledge that has been used by the evidential reasoning process in the OMIRGS prototype. The constraints used by the evidential reasoning process of OMIRGS include: the spectral constraints (e.g. the compositional relationships between land cover and land use classes), the spatial constraints (e.g. the range values of the texture measurements of Angular Second Moment, Correlation and Entropy for land use features), and the feature constraints (e.g. the compositional value of slope and contour feature and the constraints provided by historical land use data).

This research exploited the application of object-based spectral, spatial and features using correspondence analysis techniques and presenting the analysis results using the composition function. For components included within a composition function, there is provision for a value (e.g. range value, compositional value) to be associated with them. However, not all relationships can be weighted, such as the compositional relationships between land cover and land use classes. The advantages of using the composition functions for presenting the knowledge come from two aspects. The first is that the knowledge can be presented explicitly. The second is that the composition function can be used to supply data for numerical evidential reasoning approaches, such as the Dempster-Shafer or Bayesian methods.

This research also includes a preliminary study of the "over-written feature" problem which is the problem of valuable features being over-written by the other features during feature extraction processes. The problem often occurs in the object-based approaches which are based on pre-defined object areas for feature extraction. Two types of "over-written feature" problem have been highlighted in this research. The first problem was caused by undefined object areas. For example, the newly developed residential sites within an agricultural land use object which has not pre-defined object in the object reference map will be over-written by the feature of agricultural land use. The second type of "over-written feature" problem was caused by wrongly defined object areas. For example, the object areas of the forest land defined in this research does not match the pre-defined boundaries precisely, the sprawling parts of the forest land which exceed the pre-defined object areas will be over-written. A set of rules has been used in this research to reduce the scale of the problem. However, further research is needed in solving the "over-written feature" problem.

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