CHAPTER 2
REVIEW OF LITERATURE

2.1 NEED FOR OBJECT BASED CLASSIFICATION

Remote sensing images, obtained from the orbiting Satellites are capable of providing quantitative as well as qualitative information about the earth objects. The availability of Satellite based land use maps, generally improved with ancillary data, and constitutes a starting point for many applications in different domains of spatial planning. There are two approaches that may be adopted to extract information. One involves the use of a computer to examine each pixel in the image individually with a view to make judgements about pixel based upon its attributes and quantitative analysis. The other approach involves a human analyst interpreter extracting information by visual inspection of an image composed from the image data, photo interpretation (Jahne 95). During the recent past, the approaches to solve this problem have been evolved from visual to digital to knowledge based methodologies. While many studies have managed to derive broad land use types present in urban areas, difficulties were encountered when trying to precisely characterise the complex intra urban patterns (Fung and Chan 1994). City planners have to account for frequent changes of land use for the development of cohesive policies. For this, they require regular, consistent and upto date information. Over the next few years, a larger number of Satellites with higher resolution will be launched to image the earth surface. These Satellites quite commonly will have a large range in the spatial and spectral resolutions. The potential of the data product will become greater for the user by quantity and quality. Therefore, a number of research questions developed
as a result of the anticipated increase in the number of sensors (Niemann et al. 1997) such as:

(i) assessment of resampling strategies for upscaling;
(ii) assessment of changing information content of varying resolution of remote sensing imagery;
(iii) automated cartographic generalization coincidental with the image upscaling; and
(iv) development of expert system to resolve scale/resolution/application question.

The complexity of classification is more in case of urban land use due to the heterogeneity found amongst and within the urban features. Hence, there is a need to incorporate the geometry, context and other image parameters along with spectral parameter for urban land use mapping through remotely sensed images. Remote sensing scientists have indicated that such indiscriminate use of knowledge from various sources and of different forms leads to better understanding of the system. The pixel based approach is complex even with additional knowledge, because it does not go anywhere near the human interpretation process. The greater ‘within class’ variability associated with the upcoming high resolution Satellites and scanned aerial photographs demand more appropriate approaches than the conventional pixel based ones. In the object oriented approach, pixels in association with their neighbours (object) are the basic working units. The objects can have the properties related to the context, texture and level along with the spectral property. The confusion in the feature space experienced in the conventional classifiers can be largely avoided using the fuzzy logic partitioning. The knowledge with respect to the structure, relationship and physical content of an image, formulated in a rule base with fuzzy logic partition control will emulate the human interpretation process more closely. Here, an attempt was made to
classify urban land use features through an object based approach, where the classification is done by a fuzzy driven rule base that contain the spectral, contextual and textural descriptors of the features and compared with conventional pixel based approach.

2.2 SYNERGIC CLASSIFICATION SCHEMES

The mapping of natural resources is all about partitioning the images in the feature space. Conventionally, the partition of the image components is based on spectral counts in the feature space. A wide variety of classifiers are available but all share a common objective, to allocate a pixel to a pre-defined class on the basis of its spectral property (Jenson 96). This statistical analysis of the radiometric property of the image is done with an assumption that an unique object interacts in an unique way. However, the ground reality is different. It can be different in two ways. Same objects interact in different manner or different objects behave much in the same way. This real world confusion is not addressed in the conventional classifiers, which leads to mixed pixel or misclassification problem. The source of misclassification can be categorized into three types:

(i) Mixture pixel – when the area covered by the pixel is composed of more than one class;
(ii) Cloudiness – due to variation in the atmospheric conditions and other disturbances like cloud; and
(iii) Sensor deterioration – sometimes the sensor sensing at various pixels tend to change in their calibration and record a wrong response.

The accuracy and reliability with which the image gets classified depends on many factors including the characteristics of the training data and
nature of classifiers (Swain 1987). Hence, scientists have been engaged in developing improved and alternative image partitioning techniques for accurate classification. Other alternative methods that make no assumption like non-parametric classifiers (Skidmore and Turner 1989) and fuzzy classifiers (Wang 1990) have also been used.

In the pixel based classifiers, use of multitemporal, multispectral information to classify dynamic land use systems is not new. Various authors have expended efforts to achieve fusion of spectral and spatial attributes to integrate knowledge from various sources. The synergism of the multisource, multitemporal remote sensing data has been tried with success in irrigated command area. The multispectral and multisource data across the total crop growth period integrated with local preferences and temporal information have also been used as information carriers to find out the approximate transplantation period (Vidhya et al. 2001). Azzali and Menenti (1986) have attempted crop mapping through interrelation between crop phenology and vegetation indices for different crops at different growth periods, employing a 'multi temporal multi index' approach based on the spectral value and vegetation indices (TVI). Toutin (1995) used Digital Elevation Model (DEM) as an additional data to spectral data for land use mapping. Recent developments in landscape ecology have emphasized the important relationship between the spatial patterns and many ecological procedures. Guan and Jong (1994) have investigated quantitative methods to determine the significance of spatially explicit procedures to develop reliable ecological models. An automated classification system based on Adaptive Resonance Theory (ART) recognized as theory of human recognition, developed by Carpenter et al. (1997) is another success story of integrated knowledge approaches with traditional classifier applied on multisource Satellite data. But the pixel based approach is still complex even with incorporation of additional knowledge.
While the limitations about the conventional parametric methods were realized, researchers engaged themselves in coining other alternative methods that make no assumption about the distribution of data. There are a number of image partitioning algorithms like boundary seeking algorithm, object seeking algorithm, conjunctive partitioning, etc., all mainly aim at deriving the decision boundaries (Muerle 1968; Robertson 1973; Kettig and Landgrebe 1976). All have some or other advantages ranging from processing time to the marginal improvement in the accuracy.

A popular non-parametric approach is Artificial Neural Network (ANN). In essence, ANN may be considered to comprise a relatively large number of simple interconnected neurons or units that work to categorize input data into output classes (Leung 1997). Many authors discussed the validity of ANN for image classification with respect its tolerance to noise, adaptability over time and flexibility to accept the varied importance of the data used, etc. (Hepner et al. 1990; Short 1991). Many of the studies applied this robust technique only for a smaller area and faced problems with larger data sets (Ryan et al. 1991). ANN is capable of forming highly non-linear decision boundaries in the feature space that makes this approach outperform the conventional ones. Actually, neural network classifiers were thought to outperform the conventional ones with no assumptions on normality (Gopal and Woodcock 1996). But it was realized that the neural nets consume a lot of time in training (Chen et al. 1995). A few adaptive neural networks have also been proposed to reduce the time for training, thus overcoming the main drawback of the use of ANNs for image classification (Heerman and Khazenie 1992). ANN used for classification of remote sensing images yielded results that are generally comparable or better than those derived from conventional methods (Giles et al. 1995). Without any further advantage over conventional statistical classification, ANN would only be suitable for data with non-normal
distribution (Foody et al. 1995). Nevertheless, use of a priori information is problematic in the ANN (Foody et al. 1992). The shortcomings of the parametric and nonparametric classifiers to incorporate the essential spatial component led ANN to lose its charm during the late 1990s against the object oriented approach.

Multispectral classifiers, both parametric and non-parametric, are point or pixel specific classifiers making use of special information alone to predict the class of that pixel, independent of the observations at other pixels. Many authors proposed approaches that address the spatial relationships to various degrees (Kettig 1976; Goldberg et al. 1988) called contextual techniques. In a sense, spatial classifiers attempt to replicate the kind of spatial synthesis done by the human analyst during the visual interpretation process.

2.3 OTHER CLASSIFICATION TECHNIQUES

Conventional multispectral classifiers, both parametric and non-parametric, are pixelspecific, dealing pixel as an independent unit and are likely to lead to misclassifications of pixels in an image. In contrast to parametric methods, contextual techniques make use of the spatial context of a pixel with the basic idea that, in any real image, adjacent pixels are related and correlated (Jensen 1986). The use of contextual techniques will usually result in a reduction of classification error rates (Jhung and Swain 1996). But they tend to be computationally more intensive than spectral pattern recognition procedures (Lillesand and Kiefer 1994). The practical use of spatial and combined spectral/spatial image classification approaches is still relatively limited because, spatial resolution of most imaging Satellites was inadequate till the recent past. With the recent and planned launch of high resolution imaging
Satellites, the scope for the use of spatial pattern recognition techniques in land use classification is an extremely promising one (Schowengerdt 1997).

Karthikeyan et al. (1994) proposed two methods for contextual classification of medium resolution data and concluded that pure mathematical models might be insufficient to incorporate contextual information available from collateral contextual information like elevation and proximity to road. This is mainly because, one really does not understand much of the human interpretation process and that comparing final products may not be a valid test. The texture measurement may be accurate but the final product is inaccurate because other aspects of the implemented logic may not emulate a human interpreter. The findings of Hodgson (1994) provided a beginning point in this direction of study. Discovering how a human determines the information from the spatial variation in tone within the window is a major step towards successful implementation of an automated classifier. Accurate discrimination between classes is particularly problematic for the per-pixel classifier even when using multispectral imagery and local spatial measurements, as the human knowledge is often inexact and uncertain. Remote sensing image classification has been considered a cognitive process and modelled with fuzzy logic framework. Formalism for drawing possibly imprecise conclusions from a set of imprecise premises is fuzzy logic, a non-standard logic for approximate reasons (Zadeh 1990). In modeling the activity of the human brain, Binaghi et al. (1997) have attempted to model Satellite image classification as a cognitive process by defining knowledge based strategy by unified contextual and multisource information. They proved that fuzzy logic framework was appropriate for modeling cognitive processes involving recognition and capturing intrinsic vagueness of the concepts involved.
2.3.1 Quest For Data Fusion

The process of drawing conclusions with approximate truth values can be considered as approximate reasoning. Leung (1989) discussed the employment of fuzzy logic for approximate reasoning in knowledge based systems. Capturing the intrinsic vagueness of the concepts involved the “non-normative” character of the theory allowing the specialization of knowledge ingredients to represent different information categories in the unified framework (Binaghi 1997). In mapping science, we are forced to use the various aspects from different sources for classification and feature extraction (Wald 1999).

2.3.2 Definition of Data fusion

A few definitions of data fusion are proposed in literature. The documents of OpenGIS consortium define fusion as “the process of organizing, merging and linking disparate information elements (eg. map features, images, text report, video, etc.) to produce a consistent and understandable representation of actual or hypothetical set of object and/or events in space and time”. In Earth Observation from Space, Genderen (1994) proposed that image fusion is the combination of two or more different images to form a new image by using certain algorithm. Mangolini (1994) extended data fusion to information in general and added reference to quality. He defined data fusion as set of methods, tools and means using data coming from various sources of different nature, in order to increase the quality of the required information. In applied mathematics and image processing, the definition proposed by Hall and Llinas(1997) also refers to information quality and details the purpose of the data fusion. But it still focuses on the methods ‘ data fusion techniques combine data from multiple sensors, and related information from associated
database, to achieve improved accuracy and more specific inference that could be achieved by the use of a single sensor alone'. Li et al. (1993) wrote "fusion refers to the combination of group of sensors with an objective producing a single signal of greater quality and reliability".

These common definitions span three level description of data fusion, at pixel level, feature level and decision level (Pau 1988; Wald 1999). Fusion offers the advantages of a better description and formalization of the potentials of synergy between the various sources of information, and accordingly, a better exploitation of this information (Pau 1988). In this study, the fusion is done at feature level since pixel is only a support of information but not semantically significant.

2.3.3 Properties of Data fusion

(i) Fusion of Attributes

It consists in merging the attributes of a same object, derived from two representation \((X_{S(1)})^t\) and \((X_{S(2)})^t\) at an instant through the source of information \(S(1)\) and \(S(2)\), in order to obtain new attributes in the space of sources \(S = S(1) \cup S(2)\).

(ii) Fusion of Analysis

This assumes that the sources of information are aligned and associated. Fusion of analysis consists of aggregating representations, \((X_{S(1)})^t\) and \((X_{S(2)})^t\), into a new representation \((X_s)^t\), and then in generating an analysis or interpretation of the object for further use at an instant \((t+1)\), or at step 1 in an iterative process.
(iv) Fusion of Representations

It is defining and performing meta-operations applicable to representations \((X_{S1})^j\) and \((X_{S2})^j\), to obtain a new representation \((X_S)^j\). Fusion of representation includes fusion of decisions.

Fuzzy set theory has recently received considerable attention from the remote sensing community. That a pixel can enjoy partial membership in given information class is an attractive alternative to the two-value logic implicit in most classification procedures. A comparative analysis was made between unsupervised classification and a fuzzy classification technique using a Landsat MSS image covering section of Mau Forest in Kenya (Manyara and Lein 1994). The results of the comparative studies revealed that the fuzzy set approach provide a more detailed and precise classification of forest cover. In the process of exploring the suitability of fuzzy theory for image classification, Manyara (1994), used fuzzy approach to estimate Kenya’s forest cover by translating a series of measures \((X)\) such that

\[
\text{FOREST} = \{X, U[\text{Forest}](X)\} \tag{2.1}
\]

where \(U[\text{Forest}]\) defines the grade of membership of brightness value \((X)\) in the class. Participation in the class ‘Forest’ for any pixel can range from 0 defining perfect non-membership to 1 describing perfect membership. The result convinced that the mixed pixels prone to the forest classification were largely eliminated.

However, full potential of fuzzy sets is not brought out for remote sensing applications. The inadequacy is largely due to the underlying membership concept of classical set theory. Wang (1999) has developed a
fuzzy supervised classification and compared with the conventional methods with respect to (a) representation of information, (b) partitioning of spectral space and (c) estimate of classification parameters. He owed the mixed pixel resulting out of the classifier to the membership assignment and the representation. Approximate reasoning techniques, based on fuzzy production rules, were applied to model the multifactorial evaluation process, defined as a set of explicit casual relationships between factors and decision rules (Binaghi et al. 1993). This explicitly describes the relationship between the contextual and multisource scheme as hierarchical relation in the overall structure.

The use of multispectral sensor fusion came in handy to solve a variety of classification and discrimination problems (Lazofson and Kuzma, 1994). They implemented unsupervised maximum likelihood and ‘fuzzy’ clustering along with Multilayer perception and Learning Vector Quantisation (LVQ) ANNs to detect targets. The results of pixel based data fusion indicated that the data fusion algorithm was not critical in solving the object classification problems. It has been pointed out that it is necessary to consider the larger context for segmentation (Masson et al. 1993). Caillol et al. (1997) reinforced this idea by introducing two approaches called contextual segmentation and adaptive blind segmentation. Carpenter et al. (1997) developed a pattern matching systems that compared the current input with a selected learned category representation or active hypothesis to generate vegetation map by the combination of fuzzy ART and maximum likelihood predictions. The authors came out with an improved approximation of the full ARTMAP by incorporating fuzzy concepts. Pixel level prediction was improved from 84% to 91% whereas site level accuracy was improved to 10/10 by the integration of real world fuzziness, meaning that object based approach is more appropriate. This implies that the fusion may operate at any of the three semantic levels: measurements, attributes and rule with possible crossing between levels. The
fuzzy driven rule base has an advantage of incorporating the real life uncertainties in the classification. The basic features of fuzzy logic can be summarized as follows (Bellman and Zadeh 1977):

(i) truth values are fuzzy;
(ii) the set of linguistic truth values is not closed under the logical connectives;
(iii) truth values are subjective and local;
(iv) validity can only be characterized semantically; and
(v) completeness, consistency and axiomatisation are peripheral.

The main reasons for the fusing image data has always been to maximize the advantages of the spectral details of the high resolution (hyper spectral) data and spatial details of the multispectral information. This has resulted in two fundamental problems, namely unmanageably large image files and loss of spectral fidelity of the fused data. The classification problem simplifies to the question of how well the physical, contextual and structural content of the image are understood and captured. The necessity to go in for more objects oriented approach for object generation at various levels was pointed out while downscaling high resolution data to segment the tree crowns was recommended by Niemann (1990). An approach, called multiresolution segmentation, developed by Niemann et al. (1998) used the spatial attributes of hyper spatial data as well as the spectral characteristics of the coarser data with range of resolutions. The segmentation approach to classification has so far been most popular in the panchromatic image application and there has been only limited progress in such approach for analysis of colour imagery and remote sensing imagery (Karthikeyan et al. 1998). It should be applicable to any complex problem in a real domain characterized by a high structure and uncertain knowledge like mapping of urban area.
2.4 EVOLUTION OF OBJECT ORIENTED TECHNIQUES

Per-segment approach as opposed to per pixel classification provides a vehicle within which the spatial variability and texture inherent in fine spatial resolution imagery could be utilized. There is an urgent need of a system, which would use various methods of segmentation and classification to unfold the information content in the high spatial resolution remote sensing data. A typical scene may consist of mainly regular and/or irregular regions arranged in a patchwork manner, each containing one 'class' surface cover type, called 'objects'. Several studies have indicated the application of structural and contextual knowledge based on the geometric and morphological properties (Leung 1997). In an object based approach, image region with certain homogeneity is the most convenient way to attach attributes of context and structure. Kettig and Landgrebe (1976) are the one who brought the concept of objects into the image processing of remote sensing data suggesting a statistical dependence between consecutive states of nature, which the sample symmetric classifiers exploit. They referred to the pixel based classification as 'no memory classification'. An interesting method where the classification of pixel on the spectral properties of its neighbour as well as its own which was described as ECHO technique (Extraction and Classification of Homogeneous Objects) paved a convenient way for further developments in object based technology. The recent literature contains a numerous references of image partitioning algorithms. Robertson (1973) divided them into two categories namely “boundary seeking” and “object seeking”. While the boundary seeking results in samples, the object seeking results in classification. The object seeking has two approaches namely, a conjunctive and disjunctive. A conjunctive algorithm begins with a very fine partition and progressively merges the adjacent elements according to certain statistical criteria (Rodd 1972; Robertson 1973). A disjunctive algorithm begins with a very simple partition and subdivides it
until each element satisfies a criterion of homogeneity. Robertson (1973) implemented a disjunctive partitioning algorithm with the same minimum distance classifier. The critical part is the generation of appropriate image regions that depend on the segmentation procedure followed (Evans 1998).

A study employed the object based approach to use the new generation Satellite for crop monitoring and the yield estimation for large disparate area (eCognition User Manual 2000). A pixel based unsupervised method and multiscale networked object based method was compared with a focus on the precision farming applications. The comparison of these two methods led to certain conclusions as below:

- Existence of the meaningful objects that contain information about their location and orientation makes it possible to automatically incorporate the spectral and spatial information that they poses in decision making process; and
- Possibility to create the finer objects that respect the boundary of their ‘super object’ provides a means to detect non-homogenous sites inside a class. The ability to construct a spectral and spatial rule about a series of surface objects of smaller area allows extrapolation and application of these rules to a wider area

Haralick (1983) coined a methodology permitting the recognition of an object in the class of objects of interest, using decision rules to decide the kind of the object on the basis the measurements made from the ground termed as pattern discrimination problem. For each pattern ‘d’ belonging to class D, a decision rule ‘f’ assigned a category alternative Ck from the set of category alternative C = {c1, ..., ck}. An algorithm developed by Kropatsch (1983) made use of an expected object shape to identify single object to minimise the time in
processing. The completeness of segmentation cannot always be postulated because there may be some unexpected regions as well as modifications of the predicted regions segmentation. Two types of information available are:

(i) Global - concerning the image formation and recording process such as the size of the pixel, the range of gray value, the geometry of the picture, etc.; and

(ii) Specific - concerning the content of the image scene such as objects which would probably appear on the image, properties and description of these objects; relative positions to each other, etc.

In all object based projects, the concept of adjacency graph of the expected regions had been utilized (Rosenfield and Kak 1982) and this method had to be improved to a hierarchical procedure by which the image graphs could be split into sub graphs. Zhao (1997) discussed a novel method for range image segmentation based on integration of edge and region information based on morphological residues. Likewise, a method proposed by Chu and Agarwal (1992) highlighted integration of multiple region segmentation maps and edge maps to operate independently from sensing modalities and processing techniques. Similarly, in an attempt to detect the low level structures, Tabb and Ahuja (1997) tried multiscale segmentation where the issue of scale selection was amalgamated with the detection process through unification of region and edge detection was achieved in the transformed domain. Comer and Delp (1999) proposed an algorithm for segmentation of textured images using a multiresolution Bayesian approach that employed multiresolution Gaussian autoregressive model for the pyramidal representation of the image. A method similar to the above was also proposed for single resolution processing to segment the image and estimate the parameters simultaneously (Comer 1994).
Contrary to the understanding of many researchers, Zelek (1990) felt that the human element is still necessary for the interpretation tasks. A perceptual grouping of edge boundary segments of narrow parallel line segments called ‘apar’ – anti parallel line pair (Zelek et al. 1988) was devised in his tool box, leaving the interpreter with interactive and selective use of the spectral and shape information. Warten and Newcomer (1987) presented a detailed report for the data processing methods that would become necessary with the deployment of Earth Observing System (EOS). The specific goals were (i) to reduce the levels of human interaction to repetitive image processing tasks; (ii) to allow the user to experiment with the ad hoc rules and procedures for the extraction, description and identification of the features; and (iii) to provide methods that are image-independent. Particularly, the potential deployment of the new and next generation high resolution Satellite has triggered the use of knowledge based systems to extract the features. This urged many investigators to concentrate on the use of expert/knowledge systems in image analysis (Tsatsoulis 1993). A lot of efforts were taken by the remote sensing researchers to classify the images with the help of knowledge systems using the object oriented approach. Now, newer pragmatic approaches like object orientation and fuzzy logic partitioning for representation and information handling are being investigated for improved feature descriptions.

2.5 DEVELOPMENT OF OBJECT BASED CLASSIFICATION

Greater details inherent with the high resolution remote sensing data is the catalyst for the development of object based knowledge. Also, cost and time involved in the manual photo interpretation and information extraction led the evolution of knowledge representation and reasoning techniques in the remote sensing arena. A number of object based image classifiers were proposed. Bucker et al. (2000) developed knowledge based automatic image
data analyser for remote sensing data called GeoAIDA with semantic network for knowledge representation. In an attempt to use such knowledge systems, Niemeyer et al. (2001) have investigated the use of medium resolution LANDSAT TM5 for the routine nuclear verification, based on canonical correlation analysis and Bayesian technique for automatic determination of significant thresholds. The same objective has been attempted with IKONOS data, which could provide large scale structural set up and small scale variations for inspection of nuclear sites (Niemayer and Canty 1999). Unlike the system, which interprets image through structural knowledge (Niemann et al. 1990), this system analyses the scene holistically. During the last decade, the classification of forest was in the focus of many remote sensing supported investigations. Forest management and monitoring with remote sensing data have a long tradition in Swiss research (Kellerberger, 1996), especially after 1999’s hurricane Lothar. Schwarz et al. (2000) evaluated the object based approach to support forest management in Switzerland and delineated damaged forest accurately, 44.7 ha. as against 40.9 ha. The implicit richness of information on high resolution data and the expert knowledge can be fully exploited with this approach. Nicolin (1987) while constructing the knowledge based interpretation system to analyze the suburban scene of aerial images introduced structural analysis as an additional process between segmentation and interpretation.

Long (2000) has designed a system to detect and quantify the scenic beauty and the vegetation structure for the United States Forest Service (USFS) and observed the importance of contextual information and syntactic constraint for a better output. Heyman (1999) applied this concept to extract Aspen (Populus Tremulodies) stands, a forest species, using rule based system. In this context DELPHI 2 ‘Image analysis’ software was launched with a fractal hierarchic segmentation algorithm, which prepares a set of spatial objects, or
local pixel groups, using a fuzzy logic classification. A MOMS-2P pilot project by Buck et al. (1999) utilised this concept for inventory of 'Protective forests' in the Bavarian Alps.

In this endeavour of more and more refined classification schemes, the concentration slowly shifted to feature extraction, triggered by the advent of high resolution Satellite systems. Most of the techniques used for road detection in visible range images are based either on conventional edge or line detectors, (Welch and Ethers 1988; Vanderburg 1976), but fail with respect to SAR images. Tupin et al. (1998) proposed an approach using segment sites to extract linear features from a SAR image. The insufficient definition of the contextual knowledge on the scale of image is overcome by defining Marcov Random Field (MRF) on the segments of the road detected. In another study to optimise segmentation through edges on SAR image, Fjortoft et al. (1998) proposed a step edge detector for SAR images under stochastic multiedge model. These methods by and large provided an efficient segmentation mean for SAR images, unlike other segmentation schemes like region growing and simulated annealing (Cook et al. 1996).

Efforts for information extraction were boosted high by the new generation Satellites, which provided a very high resolution data. Big questions placed in front of the scientific community were 'How to build meaningful objects, which coincide with the pattern of reality?' and 'How to include neighbour information across several spectral bands for a pixel based analysis? ’ Several groups attempted to achieve this by using pre-defined boundaries applicable for discrete land cover classes. And for a land cover without boundary, image segmentation came in for the rescue. Especially within the last two years, many new segmentation algorithms as well as applications were developed, but not all of them led to qualitatively convincing results while
being robust and operational. A new algorithm called ‘fractal net evolution approach’ (Baatz and Schape 2000) may eventually revolutionize the image processing of remotely sensed data. Here, a hierarchical tree of image objects is generated wherein each object knows its neighbouring objects in horizontal and vertical direction. The generated segments act as image objects whose physical and contextual characteristics can be described by means of fuzzy logic. Software termed as *eCognition* is launched, which is completely object oriented, and uses patented, multiscale image segmentation approach. The advent of high resolution remote sensing data has now prompted the image analysts to go in for more intelligent systems to capture the load of information and use them for intelligent classification. The most promising approach at this information era would be the knowledge systems that capture the features in all their meaningful depictions for object identification and information extraction. The potential deployment of Earth Observing System [EOS] has catalysed increased research in the use of expert/knowledge systems for classification.

### 2.6 KNOWLEDGE BASED IMAGE ANALYSIS

Considerable efforts incorporating the recent achievements of statistical, theoretical decision approaches, neural networks and knowledge based classification paradigms have been dedicated to classification and recognition problems in image analysis. They still cannot be compared with human capabilities in solving classification problem in the real world (McKweon 1985). Human interpreter implicitly uses the structural knowledge like shape and spatial relation along with the contextual information. Numerous systems to automate image classification based on the spectral information have been proposed to enact the capacity of the human being in decision making. However, there has been only a little progress in combining expert systems and remote sensing applications. A very early application of expert system
concentrated on tracing forest profile changes in time (Goldberg et al. 1985), which performed the classification and a temporal classification was compared to detect the changes. In another attempt, a non-parametric classifier located seven type of Eucalyptus (Skidmore 1989). Most of these knowledge systems require the user to input the description of the data on a higher conceptual level. Issues like knowledge representation and evidential reasoning have been discussed by various investigators. By knowledge based image analysis, it is meant that a series of transformations that start with an image which is an array of sample values or pixels, and end up with a symbolic descriptions of their content or meaning (Campbell and Roelofs 1984). The use of knowledge spared by experts and other sources through a dedicated system for remote sensing analysis is as old as 1980s. A surprising number of researches have concentrated on expert systems in the process. Such intelligent assistant systems contain knowledge about various data sources and the abilities of processing and classification algorithms to extract information from the data. An early effort used an expert system to help the user to operate LANDSAT Digital Analysis System (LDIAS) at Canada Centre for Remote Sensing (Goodenough and Zelek 1987). Another information retrieval system, used information on image profile, the goals and strategies for applying algorithms (Smyrniotis and Dutta 1988). An expert system even suggested an algorithmic method to classify image from its profile (Tjahjadi and Henson 1989).

The use of such knowledge based systems ranges widely from the recommendations of the processing techniques to specific resource applications. So far, expert systems demonstrated only the viability of such approach rather than giving a one-stop solution for all problems of classification. An environment, called l-see, was developed to support the implementation of image understanding applications (Fierens et al.1989). A classification system described by Dellepiane et al. (1988) used intensity and
texture segmentation on SAR images to input a rule based system. In the early 1980s the arctic sea ice tracking was done by manual tracking in the sequential image frames. Vessecky et al. (1988) suggested a combination of area correlation and feature tracking whereby feature tracking provides an initial estimate for area correlation. This kind of synthesis between area correlation and feature tracking has been recently implemented in the ice motion portion at the Alaska SAR facility (Kowk et al. 1990). Daida et al. (1994) came up with an image understanding based system to manage the tracking algorithms with domain independent knowledge management using modified JCLUST algorithm (Wilson and Span (1988), which reduced the false alarm rates with hierarchical correlation tracking.

While the region based systems were developed, the task of image region generation was done some production systems (Nasif and Levine 1984; Corr et al. 1988). Srinivasan and Richards (1990) demonstrated the use of AI-related techniques to achieve the integration of several sources for classification using Dempster-Shafer and qualitative reasoning. Lu and Kay (1989) even discussed the intelligent integration techniques to extract objects from aerial images for map updating. Due to the growing ability of GIS, the map data could be accessed by computers directly and is therefore usable for the automatic interpretation of aerial images. Growe (1999) developed a method that used state transition graphs to formulate temporal changes. Same idea was followed to extract an industrial fair ground. Thus, the knowledge based scene interpretation became promising approach in the field of image understanding. With this idea, Liedtke et al. (1997) tried to improve the AIDA that added region based and holistic analysis to geoAIDA. While addressing the problem of integration of remote sensing and GIS, McKeown (1987) emphasized on the need for awareness of the source, accuracy and reliability of the data. His idea was more on the integration of remote sensing and GIS for seamless
information processing and handling. He has also suggested the usefulness of the rule base for interpretation of the images and transport of this information to a GIS (1985).

Schiewe et al. (2001) pointed out that a segmentation should allow a parallel segment generation and information fusion of feature level. To translate spectral characteristics of an image object to a real world feature, the object oriented classification approaches use semantic based on description, assessment and knowledge (Blaschke and Strobl 2001). Feasibility of this methodology was tested in a project to automatically detect houses from High Resolution Stereo Camera data by Hoffmann and Vegt (2000). This approach was further examined by Niemeyer and Canty (2001) for the possibility of knowledge based classification for the change detection and object recognition in the context of nuclear safeguard. Benz et al. (2001) found that the new approach of fuzzy, object oriented rule based classification by software eCognition allows modelling the relationships alpha-entropy-anisotropy feature space and basic land cover classes.

In general, expert systems have found applications in the creation 'smart' user interface for assistance in using complex analysis and interpretation, but most of them are prototypical. It is also suggestive from the literature that a smaller specific knowledge system can do a better job than a algorithmic program like Artificial Intelligence. Nevertheless, the future of the use of domain specific knowledge through data models embedding the knowledge is very bright in remote sensing classification problems. Especially, the knowledge systems are more objective in the domains with rigid structure like drainage, urban, etc.
Knowledge of land use and land cover is important for many planning and management activities. Land use refers to man’s activities on land, which are directly related to land. Dunn and Harrison (1990) stated that ‘Land use is notoriously difficult to classify and measure even within small areas: and numerous problems are encountered in designing system for classification for land use survey’. The availability of Satellite based land use maps, generally improved with ancillary data, and constitutes a starting point for many spatial planning. The traditional method to get information on land use is based on the visual interpretation, which is time consuming and labour intensive. For the first time, high resolution data like IKONOS with about 4 meter resolution in multispectral mode and 1 meter resolution in panchromatic mode, offer potential to map urban areas at a scale unattainable earlier. Over the years, Satellite data have been successfully utilized for mapping, monitoring, planning and development of urban sprawl, urban land use and urban environment. Variety of techniques are available for discriminating the basic entities of an urban scene (buildings, road, open spaces) starting from unsupervised per pixel classifiers to sophisticated segmentation algorithms, such as region growing or split and merge procedures, which take the neighbouring pixels into account. While many studies have managed to derive broad land use types present in urban areas, difficulties were encountered when trying to precisely characterize the complex intraurban patterns (Fung and Chan 1994). Landgrebe (1999) identified the challenges for image processing which, principally arises from the fact that

(i) there are many different materials used in the building roofs of the area, and they are of various ages, and a variety of conditions, and

(ii) some of the materials used in the roof are similar to that in streets.
Though remote sensing is defined as "scanning the present and resolving the future", automatic information extraction for operational use is still in its beginning. High resolution earth observation Satellites with resolution ranging from 1 meter to 5 meter are expected to usher in an exciting new era of geospatial data collection, topographic mapping and remote sensing application. Chao and Trinder (2000) examined the knowledge representation and object modelling to extract features from digital aerial images. The object recognition techniques based on semantic proved that domain knowledge was necessary to address the adjacency, coexistence and relational structures between different objects and classes. A domain dependent relation took this fact into consideration in the generic model (Growe et al. 1999). As an illustration, a major road inherits the properties of road and posses an additional crash barrier. For the part-of relation between pavement and road the domain urban scene was defined. A hypothesis that has not yet been tested in the sensor data is neither necessarily right nor wrong (Tonjes and Growe 1998).

Schiewe et al. (2001) employed multiscale segmentation of an urban area in Germany to evaluate the potential of region based methods in remote sensing problems. They found that geometrical accuracy and morphological correctness were determined by the resolution of the data. The best segmentation results were achieved with different spectral combinations and weighting factors or different bands with respect to object classes. As studies have proven, high resolution of the data does not automatically lead to higher classification accuracy. So, Bauer and Steinnocher (2000) carried out a land use inventory and the resulting information was integrated in a rule base with IKONOS data for the city council of Vienna. The structural compositions of different land use categories were used for the definition of rules and it was found that the better the definition of single objects, the better would be the resulting land use information.
Dynamic and textural urban object classes must be captured with respect to their structural, textural and spectral properties (Vidhya 2001). Especially settlements in an agglomerated urban area hold typical textural and structural information, which are mostly determined by their formal/informal status. Hoffman (2001) used PAN sharpened image end elevation information to detect the building from IKONOS data. He generated hierarchical segments at different levels by introducing the spatial relationships horizontally and vertically. In housing and rural settlement areas with typical heterogeneity, elevation details come in handy to detect objects. The parameters of the homogeneity selected for a specific study is unique to the classes, meaning that the classification strongly depends on the initial segmentation. The use of elevation in urban object detection helps differentiating the shadows and houses. The information of forms and context can be added for detection of the linear objects like roads.

The process of detecting informal settlements, a phenomenon in developing countries, might be the most challenging task because of its mixed texture and structure. Different types of informal settlements based on their status were classified using multilevel segmentation and class hierarchy (Hoffmann 2001; Mason and Fraser 1998). It would also help to use stepwise refinement of the classification that resembles the elimination keys (Lillesand and Kiefer 1994). Almost all studies concern with finer object detection needs proper ground information about the structure, etc. Once a representative rule base for an appropriate segmentation procedure is evolved, the classification results can be used as input for periodical updating of the urban mapping (Tonjes 1997).

The future of the use of domain specific knowledge through data models embedding the knowledge is very bright in remote sensing
classification problems. From the above discussion, the use of object based approach seems to be promising in urban land use mapping activities. The definite structure and the physical characteristics of the most of the urban features can be more effectively exploited by the object based classification. Various urban features could be described well in different scales, suggesting use of a multistage segmentation. The effectiveness of the rules formulated with the physical, relational and structural properties of the urban land use classes depends on the way the class properties are abstracted. A fuzzy driven rule base would emulate the human interpretation process more closely than any other method.

2.8 SUMMARY

So far, the knowledge bases and fuzzy partitions have been developed for a very specific problem or feature. It is also necessary to formulate a rule base that describes different classes of a classification system for operational use. Such a knowledge base should be adaptable to similar urban areas elsewhere with little or no modification. Therefore, a generic knowledge base applicable to major urban environment will be helpful in studying the urban land use variation and appropriate planning. Hence, this study concentrates on the use of object based knowledge management through fuzzy-driven rule base for level 3 urban land use classification upto types of residences, using high resolution remote sensing data such as IRS1C PAN, resolution-merged (IRS 1C PAN + LISS III) and IKONOS data. Such a detailed urban land use mapping is necessary for proper city planning and related resource allocation.

In the recent past, the advances in image processing techniques are being focussed towards feature extraction, especially because of the upcoming
high resolution Satellite data. However, the research with pixel based approaches have been observed to be inconsistent not capable of handling structural and contextual information. The natural spatial dependency of the earth objects to each other are handled better by the object based approaches. The inclusion of additional knowledge for feature extraction is made easier by the knowledge bases with a proper strategy. Periodic assessments of the changing land use with proposed methodology will help in planning process. In this study, a knowledge base is constructed to work on objects to derive urban land use. This study also evaluates this approach on various medium to high resolution remote sensing data. The literature reviewed above would stand and aid towards developing a methodology for object based image analysis for extracting information from the remote sensing data, especially from high resolution data.