GIS SMART MAPPING TECHNIQUE FOR URBAN SPATIAL PATTERN ANALYSIS – A CASE STUDY ON NIBONG TEBAL SUB-DISTRICT

By

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ABSTRAK

Kajian ini membangunkan kaedah pemetaan yang cepat, teknik pemetaan yang menjimatkan kos dan memantau ciri-ciri permukaan bumi menggunakan gambar foto daripada pengimbas satelit beresolusi tinggi yang dilengkapi dengan rangka kerja data GIS. Kaedah ini terbukti berupaya menentukan perubahan pada permukaan bumi di daerah Nibong Tebal melalui analisa paten ruangan GIS. Kajian ini melibatkan beberapa peringkat kerja iaitu pra-kajian, soroton literatur, pembangunan pangkalan data, pengumpulan data, aplikasi perisian, kemasukan data, analisis data dan hasil kajian. Terdapat lima kaedah dalam analisa ruangan yang dijalankan iaitu persampelan semula, pengklasifikasian, penukaran vektor-raster, penjadualan rentas rajah, analisis paten ruangan dalam menganalisa dan mengenalpasti perubahan pada bentuk muka bumi. Hasil kajian menunjukan terdapat perubahan pada kawasan membangun dan begitu signifikan ekoran daripada pertambahan kawasan tempat tinggal dan kawasan yang berpotensi dari segi ekonomi. Selain itu, hasil kajian juga menunjukan pengurangan yang berlaku kepada kawasan pertanian seperti tanaman kelapa sawit dan ladang getah kesan daripada pembangunan yang pesat. Dalam pada itu, terdapat juga perubahan kecil terhadap laluan aliran sungai yang kemungkinan berpunca daripada kesan hakisan dan pertambahan laluan jalan raya di kawasan tersebut. Kesimpulannya, kajian ini memberikan output yang berguna dalam menerangkan proses saling guna maklumat yang diperolehi daripada satelit dengan data ruangan dalam kajian pengesanan perubahan terhadap guna tanah.

ABSTRACT

This study developed and validate a new fast, cost-benefit technique of mapping and monitoring urban land cover characteristics using high resolution satellite sensor images integrated with digital 'framework' of GIS data. This technique has successfully determined the extent of the urban land cover changes in Nibong Tebal sub-district by means of GIS spatial pattern analysis study. The research covers several stages of work including pre-research, literature review, database development, data collection, system software application, data entry stage, data analysis and data output stage. There are five methods of spatial analysis that have been carried out, namely resampling, classification, raster-vector conversion, image cross-tabulation, and spatial pattern analysis in analyzing and detecting the urban land cover changes. The results showed that there are changes in the built-up/urban area and were very significant due to the expansion of the residential and commercial area. The result also indicated the decrease of the agricultural area such as oil palm and rubber plantations due to the rapid urban expansion. Other results obtained in this study showed some minor changes in the river outline probably due to the errosion and the increase of sub-district roads over the areas. In conclusion, this research provides useful results in demonstrating a process of integrating information derived from satellite imagery with other spatial data in land use change detection study.

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CHAPTER 1

INTRODUCTION

1.1 Background

Over the last two decades, land use changes have become very dynamic and the changes in the land cover have become very drastic in the urban and rural areas. Particularly, more land areas have been converted to non-agricultural activities such as industrial, housing and commercial areas.

GIS is a system for capturing, storing, checking, manipulating, analyzing, and displaying data which are spatially referenced to the earth (Brian E. Mennecke, 2004). Fundamentally, a GIS is a tool for linking attribute databases with digital maps. GIS does not only provide users with an array of tools for managing and linking attribute and spatial data, but they also provide users with advanced modeling functions, tools for design and planning, and advanced imaging capabilities. While many of these capabilities also exist in other type of systems, such as visualization and virtual reality systems, GIS are unique because of their emphasis on providing users with a representation of objects in a cartographically-accurate spatial system and on supporting analysis and decision making (Brian E. Mennecke, 2004).

The application of Geographic Information System (GIS) in urban mapping provides a new fast, cost-benefit technique of mapping and monitoring land cover characteristics within and around urban areas using high resolution satellite sensor images integrated with digital 'framework' of GIS data. It also has the ability to map and classify the spatial pattern of land cover and identify detailed features of urban land across the study area by means of automatic updating especially in road and traffic network mapping.

1.2 Problem Statement

The rapid development of the concept of vegetation mapping has lead to increased studies of land use and land cover change worldwide. The progress of research and development through remote sensing technology has performed a new dimension of analyzing patterns of land use or mapping the land. The use of remote sensing utility such as satellite images has become an essential roll in collecting land information or primary data (Muzailin, 2003).

Land use information of various levels for development planning in the country including land utilization and land use activities namely urban land development, forestry and fisheries, will provided by the integration of Geographic Information System (GIS) and Remote Sensing technology. The knowledge of land use and land cover is important for planning, development and management activities that are concerned with the earth surface. The information on the spatial pattern and temporal dynamics of land cover in Malaysia both within and around urban areas is critical to be address within a wide range of practical problems relating to urban regeneration, urban sustainability and rational planning policy.

There is no currently new technique available for updating the urban land use map. The current JUPEM data available is not up to date. With the advanced of high resolution image (e.g. QuickBird Ortho Satellite Imagery Systems) there is possibility that land cover characteristic can be update in the fast cost benefit technique.

1.3 Research Aim

The objectives of this study are:

i. To develop and validate a new fast, cost-benefit technique of mapping and monitoring land cover characteristics within and around urban areas using high resolution satellite sensor images integrated with digital 'framework' of GIS data.

ii. To determine the extent of the urban land cover changes in Nibong Tebal sub-district by means of spatial pattern study.

1.4 Study Area

The study area is the Nibong Tebal sub-district located in the southern part of the Seberang Perai, State of Pulau Pinang is shown in the Figure 1.0.

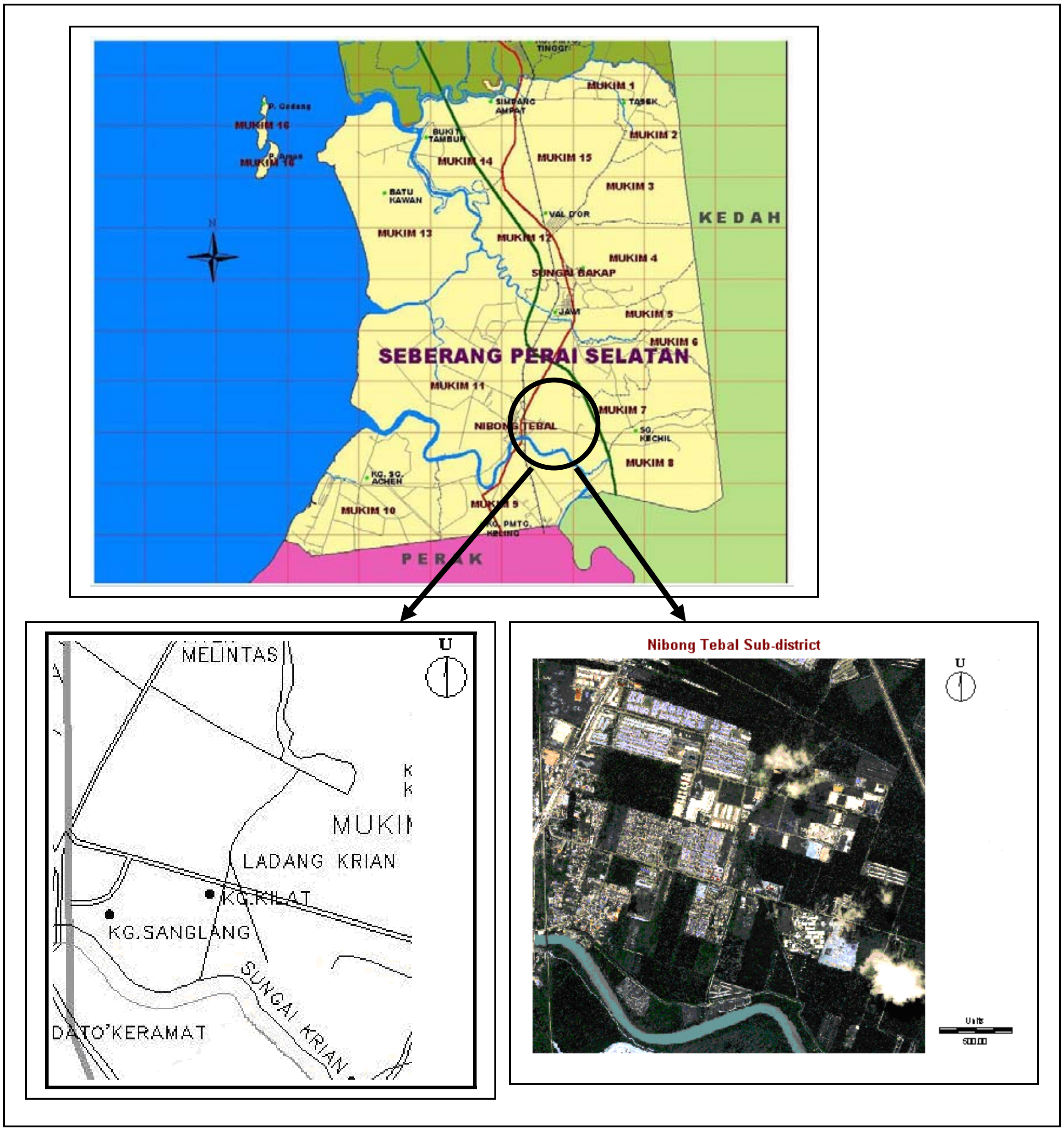

Figure 1.0. Study Area at Nibong Tebal Sub-district, Pulau Pinang.

1.5 The Benefit of this Project

The GIS allows us to create many maps in various forms based on a wide variety of analyses and on an increasingly large set of spatial data. In fact, the advent of readily available databases is in large part a response to the increasing availability of GIS software. This power makes an understanding of map design more important than ever, especially because the majority of GIS analysts today have limited experience with cartographic production and design. More important, because there are now more users of maps of many different types (e.g. in Civil Engineering), the requirements for an effective communication become even more necessary.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Geographic Information Systems (GIS) technology has been rapidly growing into practical applications for municipal, public, and private agencies during the last two decades. GIS consists of a data base containing spatially referenced land-related data, as well as the procedures and techniques for systematically capturing, storing, retrieving, analyzing, processing, updating, and displaying that data (Al-Naqi, 1988). GIS enables the user to manage geographic data more efficiently and can enhance the decision-making process for planning purposes.

The integration of Geographic Information System (GIS) and Remote Sensing technology can provide land use information of various levels for development planning in the country including land utilization and land use activities namely urban land development, forestry and fisheries, etc. The information on the spatial pattern and temporal dynamics of land cover in Malaysia both within and around urban areas is critical to be address within a wide range of practical problems relating to urban regeneration, urban sustainability and rational planning policy.

Satellite sensor images are a convenient source for separating urban built from open spaces and vegetation, and to some degree where image data fall short, support can be given from the growing number of new digital GIS 'framework' datasets. The advent of high resolution optical sensors of satellite remotely sensed data (*e.g.* IKONOS, QUICKBIRD systems) provides a powerful tool to provide this spatial information in both a timely and spatially consistent manner (S. Ahamad, M.S., 2004). Such ancillary data can be used in a number of ways to augment satellite images and produce improved urban land-cover measurements and classifications.

2.2 Traditional Map versus Automated Mapping

Traditional maps are abstractions of the real world, a sampling of important elements portrayed on a sheet of paper with symbols to represent physical objects (Qiaoping and Isabelle, 2004). Topographic maps, for example, use contour lines to show the shape of land surface. The real shape of the land can only be assumed and visualized in the mind's eye. Graphic display techniques in GIS make relationships among map elements visible, heightening a person's ability to extract and analyze information. This information can then be used to generate statistics, measure distances and areas, develop new cartographic models, propose new sets of research questions, or design and print hard copy maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies (Qiaoping and Isabelle, 2004).

The updating of urban land use map is critical to many GIS application. This analysis will present a comprehensive framework for urban land use map, in which the following methods will apply:

i. Resampling
ii. Digitizing
iii. Classification
iv. Raster-vector conversion

v. Buffer

vi. Image cross tabulation

vii. Spatial pattern analysis

Keeping the urban land use map up-to-date is important to many GIS applications (e.g., urban planning, etc). In the geomatics community, there are several options in updating a urban land use map, such as ground surveying, vector map comparison, image-based updating, and etc. Image-based updating is based on feature extraction from remotely-sensed imagery, which has become even more important recently because of the high spatial resolution, fast orbit repeatability, rich multi-spectrum information and stable, affordable acquisition cost of satellite imagery. Research on image-based geospatial change detection is rather limited, when compared to the body of work on object extraction (Qiaoping and Isabelle, 2004).

2.3 Map Conversion and Data Representation

Map act as storehouses for spatial information about features on the earth's surface. This information consists of the location of points, the paths of lines, the outlines of areas, and the complex interrelationships between the various types of features. The process of converting map data from its original, visual form to a digital format that can be handled by a computer is called digitization or conversion.

A Geographic Information System stores two types of data that are found on a map i.e, the geographic definitions of earth surface features and the attributes or qualities that those features possess (S. Ahamad, M.S., 2004). Not all systems use the same logic for achieving this. However, nearly all uses one or a combination of both of the fundamental map data model namely the vector and raster data.

2.3.1 Vector Data

With vector representation, the boundaries or the course of the features are defined by a series of points that, when joined with straight lines, form the graphic representation of that feature. The points are encoded with a pair of numbers giving the X and Y coordinates in systems such as latitude/longitude or Universal Transverse Mercator grid coordinates. The attributes of features are then stored with a traditional database management (DBMS) software program. For example, a vector map of property parcels might be tied to an attribute database of information containing the address, owner's name, property valuation and land use. The link between these two data files can be a simple identifier number that is given to each feature in the map (S. Ahamad, M.S., 2004).

2.3.2 Raster Data

The second major form of representation is known as raster. With raster systems, the graphic representation of features and the attributes possess are merged into unified data file. In fact, typically it does not define features at all. Rather, the study area is subdivided into a fine mesh of grid cells in that record the condition or attribute of the earth's surface at that point. Each cell is given a numeric value which may then represent a feature identifier, a qualitative attribute code or a quantitative attribute value. For example, a cell could have the value "6" to indicate that it belongs to District 6 (a feature identifier), or that it is covered by a soil type 6 (a qualitative attribute), or that it is 6 meters above sea level (a quantitative attribute value).

Although the data stored in these grid cells do not necessarily refer to phenomena that can be seen in the environment, the data grids can be thought of as images or layers, each depicting one type of information over the mapped region. This information can be made visible through the use of a raster display. In a raster display, such as the screen on computer, there is also a grid of a small cell called *pixels*. The word pixel is a contraction of the term picture element. Pixels can be made to vary in their color, shape or grey tone. To make an image, the cell values in the data grid are used to regulate directly the graphic appearance of their corresponding pixels. Thus in a raster system, the data directly controls the visible form (S. Ahamad, M.S., 2004).

2.4 Urban Land Use Map Updating

Urban land use change detection/updating and spatial-temporal GIS have been under research for more than a decade now. There are a lot of new ideas and new approaches promoted in both areas. However, most of the research is carried out separately and very few people are working on both problems simultaneously. The spatial-temporal perspective will be very helpful to develop an operational system for urban land use change detection and map updating. On the other hand, changes detection and updating perspective will also shed some light on the research of temporal GIS.

Urban land use maps could be updated by ground surveying, either by using a traditional method (total station, Global Positioning Satellite (GPS)) or by using a more automatic method (e.g., mobile mapping system). Usually, a survey team will be informed that some urban land use have been changed, visit the site and record the new positions of the urban land use. From a spatial-temporal point of view, this method is most suitable because only the changed urban land use should be taken into account and the time stamps could be easily put either at the tuple level or at the attribute level. In addition, the change is closely linked to the events which had caused the urban land use to change. The minus of this method is that it needs many surveyors to focus on this task in order to record the change timely. Therefore, it is a costly and labour intensive way to update a urban land use database.

The second method is to use a more recent map to update the old road map. By feature matching, the unchanged and changed urban land use can be determined during the mapping time interval. This is an ad-hoc technology to maintain a urban land use database. The revision time may be one year or more than five years depending on the application purpose and other situations. It is obvious that this method is close to a snapshot approach to model the changes. A change has a very coarse temporal resolution. It may also be very difficult to determine when the road changes occurred because there is little information about the events which caused these changes. The transaction time/database time can be indicated at a table or tuple level because all the changes have the same transaction time. The valid time is difficult to determine unless all the changes have been recorded immediately after their occurrence.

The third method is to extract the urban land use and detect the changes based on new remotely-sensed imagery. This technology has been widely researched for many years. Although there are few successful fully automated techniques, there are many partially automated feature extraction techniques available to detect urban land use changes. The limitation is identical than for the second way same transaction time for all the urban land use changes and difficulties in identifying the valid time of the changes. Figure 2.0 shown an example the use of GIS map conflaction in urban analysis and Figure 2.1 shown an example the road and highway network satellite image.

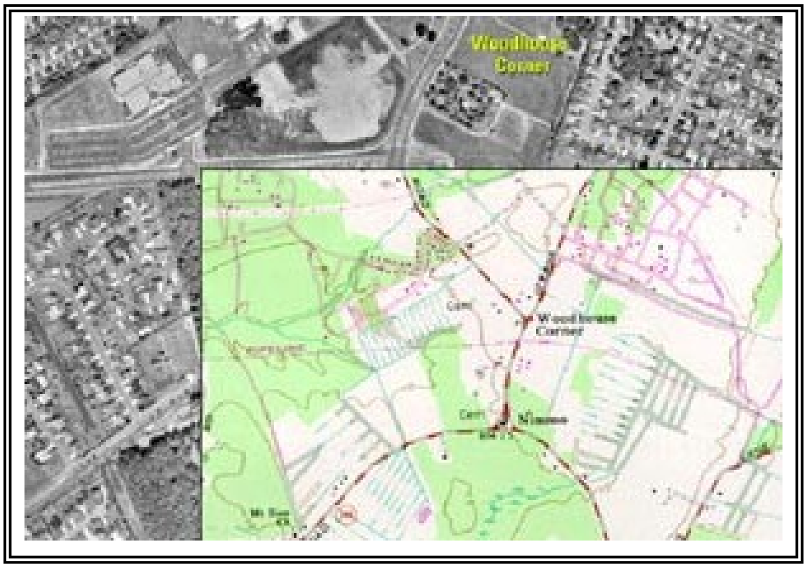

Figure 2.0. Use of GIS map conflation in urban analysis.
(*Source:* QUICKBIRD Image, 2004.)

Figure 2.1. Road and highway network satellite image.
(*Source:* QUICKBIRD Image, 2004.)

2.5 Framework to Urban Land Use Map Updating

Naturally, an operational urban land use map updating system should include the following three main functions:

i. Generating a new version of urban land use features or the whole urban land use either by urban land use extraction from imagery
ii. Detecting urban land use changes, i.e. identifying the urban land use that remain unchanged, have disappeared, or emerged recently
iii. Updating the urban land use map.

Map conflation techniques can then be applied for urban land use change detection and updating. Finally, the change information of the urban land use is organized in an efficient way to facilitate spatial-temporal queries and spatial-temporal analysis.

2.6 Summary

Urban land use change detection/updating and spatial-temporal GIS have been under research for more than a decade now. In the geomatics field, urban land use change detection and database updating based on remotely-sensed imagery has been the objectives of many projects. In an operational urban land use database updating system, seven heuristic process have to be included, namely resampling, digitizing, classification, raster-vector conversion, buffers, image cross tabulation, and spatial pattern analysis.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains and elaborates the process and the study methods implemented in this project. This is appropriate to obtain the best approach of the study in order to get exact and accurate output. Via systematic procedure, research methodology is formed to help in determining the relevant procedures for smart mapping in the study area of Nibong Tebal sub-district. In addition, this chapter explains the applications of GIS system and data in the study process.

3.2 Methodology

In order to get into detail about this research that has to be implemented, the several stages are described by the flowchart in Figure 3.0. The stages are comprised of the following:

i) Pre-research

ii) Literature Review

iii) Database Development

iv) Data Collection

v) System Software Application

vi) Data Entry and Conversion Stage

vii) Analysis and Output Stage

viii) Summary