SEMI-AUTOMATED APPROACH FOR MAPPING URBAN TREES FROM INTEGRATED AIRBORNE BASED DIGITAL IMAGE AND LiDAR POINT CLOUD DATASETS

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This thesis is dedicated to Allah (SWA) for his infinite mercies and blessings upon me throughout the period of my study.

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ABSTRACT

Mapping of trees plays an important role in modern urban spatial data management, as many benefits and applications inherit from this detailed up-to-date data sources. Timely and accurate acquisition of information on the condition of urban trees serves as a tool for decision makers to better appreciate urban ecosystems and their numerous values which are critical to building up strategies for sustainable development. The conventional techniques used for extracting trees feature include ground surveying and interpretation of the aerial photography. However, these techniques are associated with some constraint, such as labour intensive field work and a lot of financial requirement which can be overcome by means of integrated LiDAR and digital image datasets. Compared to predominant studies on trees extraction mainly in purely forested areas, this study concentrates on urban areas, which have a high structural complexity with a multitude of different objects. This study presented a semi-automated approach for extracting urban trees from integrated airborne based LiDAR and multispectral digital image datasets over Istanbul city of Turkey. The presented approach includes extraction of shadow free vegetation areas from digital images using shadow index and NDVI techniques, automated extraction of 3D information about vegetation areas from integrated processing of the datasets, extraction of tree objects from the vegetation based on various LiDAR attributes and finally, accuracy assessment of the extracted trees. The quality measures of this approach reveals that the extracted result is 83% complete and 80% correct. The developed algorithms have shown a promising result which proved that the integrated datasets is a suitable technology and viable source of information for urban trees management. Furthermore, the approach has also proved to be an accurate, fast and cost effective technique for estimating and delineating 3D information about trees. As a conclusion, therefore, the extracted information provides a snapshot of location, and extent of trees in the study area which will be useful to city planners and decision makers to understand how much canopy cover exists, identify new planting, removal, or reforestation opportunities and what locations have the greatest need or potential to maximize benefits of return on investment. It can also help track trends or changes to the urban trees over time and inform future management decisions.

ABSTRAK

Pemetaan pokok memainkan peranan yang penting dalam pengurusan data spatial bandar moden, kerana banyak manfaat dan aplikasi mewarisi ini terperinci up-to-date sumber data. Pengambilalihan yang tepat dan maklumat mengenai keadaan pokok bandar berfungsi sebagai alat untuk pembuat keputusan untuk lebih menghargai ekosistem bandar dan banyak nilai-nilai mereka yang kritikal untuk membina strategi untuk pembangunan lestari. Teknik-teknik konvensional digunakan untuk mengeluarkan pokok menampilkan termasuk ukur tanah dan tafsiran fotografi udara. Walau bagaimanapun, teknik ini dikaitkan dengan beberapa kekangan, seperti tenaga kerja yang ramai kerja lapangan dan banyak keperluan kewangan yang boleh diatasi dengan cara LiDAR bersepadu dan dataset imej digital. Berbanding kajian utama di atas pokok pengekstrakan terutamanya di kawasan semata-mata hutan, kajian ini menumpukan kepada kawasan bandar, yang mempunyai kerumitan struktur yang tinggi dengan pelbagai objek yang berbeza. Kajian ini dibentangkan pendekatan separa automatik untuk mengeluarkan pokok bandar dari LiDAR berdasarkan udara bersepadu dan multispectral dataset imej digital ke bandar Istanbul Turki. Pendekatan kali ini termasuklah pengambilan bayangan kawasan tumbuh-tumbuhan bebas daripada imej digital menggunakan indeks bayangan dan teknik NDVI, pengekstrakan automatik maklumat 3D mengenai ciri-ciri pokok dari set data bersepadu dan akhirnya, penilaian ketepatan pokok diekstrak. Langkah-langkah yang berkualiti pendekatan ini mendedahkan bahawa keputusan yang diambil adalah 83% selesai dan 80% betul. Algoritma maju telah menunjukkan hasil memberangsangkan yang membuktikan bahawa dataset bersepadu adalah teknologi yang sesuai dan sumber yang berdaya maju maklumat untuk pengurusan pokok bandar. Tambahan pula, pendekatan ini juga telah terbukti menjadi satu, teknik tepat cepat dan kos efektif untuk menganggarkan dan menggariskan maklumat 3D mengenai pokok. Kesimpulannya, oleh itu, maklumat yang diekstrak menyediakan gambar lokasi, dan tahap pokok di kawasan kajian yang akan berguna untuk perancang bandar dan pembuat keputusan untuk memahami berapa banyak perlindungan kanopi wujud, mengenal pasti peluang penanaman, penyingkiran, atau penanaman semula hutan baru dan apa lokasi mempunyai keperluan atau potensi besar untuk memaksimumkan manfaat pulangan ke atas pelaburan. Ia juga boleh membantu trend trek atau perubahan kepada pokok bandar dari semasa ke semasa dan memaklumkan keputusan pengurusan masa depan.

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ALS	Airborne Laser Scanning
APAR	Absorbed Photo-synthetically Active Radiation
CHM	Canopy Height Model
CIR	Colored Infrared
CO_2	Carbon Dioxide
DBH	Diameter At Breast Height
DCHM	Digital Crown Height Model
DCM	Digital Crown Model
DEM	Digital Elevation Model
DMC	Digital Mapping Camera
DTM	Digital Terrain Model
DSM	Digital Surface Model
DVI	Difference Vegetation Index
EVI	Enhanced Vegetation Index
FN	False Negative
FP	False Positive
GCP	Ground Control Point
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphic User Interface

IMU	Inertial Measuring Unit
INS	Inertial Navigation System
ITD	Individual Tree Detection
IPCC	International Panel on Climate Change
LAI	Leaf Area Index
LiDAR	Light Detection and Ranging
LULC	Land Use or Land Cover
MSAVI	Modified Soil Adjusted Vegetation Index
NDVI	Normalized Difference Vegetation Index
nDSM	Normalized Digital Surface Mode
NIR	Nearest Infrared
PVI	Perpendicular Vegetation Index
RATIO	Ratio Vegetation Index
RGB	Red Green Blue
SAVI	Soil Adjusted Vegetation Index
SATVI	Soil Adjusted Total Vegetation Index
SI	Shadow Index
TOF	Time of Flight
TP	True Positive
TVI	Transformed Vegetation Index
UTC	Urban Tree Canopy
VI	Vegetation Index
WDRVI	Wide Dynamic Range Vegetation Index
WMA	World Meteorological Association

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Urban trees have many advantages such as preserving energy, improving water quality, minimizing greenhouse gasses and many other environmental pollutants, as well as connecting urban dwellers with nature (McPherson, 2006). To exploit these benefits, information about location, composition and extent of urban trees is often needed for planning and management purposes. This information can be employed for a different type of analysis, like vegetation growth tracking or monitoring, appraisal of tree condition, etc. Urban forests stand for a reasonable fiscal expenditure for cities. In spite of efforts and capital spent on the conservation of trees, many cities often do not have an all-inclusive information on their conditions. In order to realize numerous economic, environmental and sustainable decision-making processes, accurate, up-to-date and in-depth information on spatial distributions, extents and health conditions of urban ecosystem is necessary. Accurate techniques for locating and mapping trees help city planners and decision makers to understand how much canopy cover exists; identify new planting, removal, or reforestation opportunities and what locations have the greatest need or potential to maximize benefits of return on investment. It can also help track trends or changes to the urban trees over time and inform future management decisions. Conventionally, this information is obtained through field surveying methods which are highly expensive, laborious (tedious), time-consuming and usually cannot be carry out over large areas. In addition, field surveying can only be carried out in areas reachable by the surveyors with insufficient or no data obtained in restricted properties and other unreachable areas. It is not easy, if not impossible, to generate information about urban trees for the whole city through field surveying. Therefore, somewhat insufficient information is obtainable about trees in many cities around the world, which is a major limitation for actualizing their benefits (Zhang, and Qiu, 2012).

Advancements in remote sensing tools have introduced laser technology which bridges the gap of satellite imagery inability to pass through the trees canopy. The technology accords distinctive advantages for management of urban natural resources. In spite of the existing usage of high-resolution satellite and airborne remote sensing data, LiDAR as a remote sensing technology, is a preference tool, which presents a promising potentiality for mapping and studying urban forests (Plowright, 2015). This is achievable with an accurate, intense and 3D mapping of natural resources which offers cost effective information especially, over a very large spatial scale in order to enhance performance in operations and decision-making processes. Light Detection And Ranging (LiDAR) is an evolving technology which has the ability to generating a well-defined 3D representation of ground surface over wide spatial scales. The distance between LiDAR sensor and terrain features can be measured with a very high degree of accuracy by estimating the time taken by the laser pulse to travel from laser instrument and then return after being reflected from terrain feature. The capability of LiDAR to pass through vegetation has attracted remarkable concern from the field of natural resources management (Hudak, et al. 2009). From a forest management standpoint, LiDAR has been used to define information about trees (Coops, et al., 2007), measure carbon stocks (Patenaude, et al., 2004), compute fuel quantity (Seielstad and Queen, 2003) and create habitat models (Vierling, et al, 2008), develop forest inventories (Woods, et al. 2008). Contemporary LiDAR systems have the ability to obtained intensive data which can identify and measure discrete trees. Even though considerable research has been carried out regarding LiDAR applications in forestry, its usage in the study of urban trees has been limited. As LiDAR applications in urban trees mapping expand, therefore, automated approach for tree detection technique is most likely to increase.

However, LiDAR systems have no band which makes it insufficient for vegetation classification, especially in urban forests with diverse species and high spatial heterogeneity. Digital multispectral imagine, usually possesses many distinct bands, therefore, exhibit a great potential in identifying and mapping tree feature with their rich spectral contents. The integrated digital image and LiDAR datasets possess huge potential in mapping urban trees. Further information can be obtained from the fusion of features derived from LiDAR and data from other sensors such as digital images. Therefore, data products which are highly information-rich can be created (Flood, 2002). Airborne LiDAR data and digital imagery are highly complementary, the images can validate the filtering accuracy while the elevation information from LiDAR can be used to ortho-rectify images datasets (Flood, 2002). Highly dense LiDAR data with multiple returns per square meter would be overwhelming for tree crown depiction and for determination of crown shape while image spectral properties can be used to differentiate tree objects (Holmgren, et al. 2008). It is assumed that both data sources concurrently will be more successful for trees detection in contrast with any of them alone. Thus, both high-resolution LiDAR data and multispectral images allow for evolving of new techniques for vegetation detection and classification (Holmgren, et al. 2008).

Therefore, it is suffices to note that integrated airborne based multispectral digital image and LiDAR point cloud datasets are suitable technology and viable source of information for city managers to analyse, evaluate, enhance urban landscape patterns and gain a better understanding of the current composition, location, extent, status and structures of trees in an urban areas.

1.2 Problem Statement

Climate change possesses a fundamental threat to the atmosphere, ecosystem, and humanity. Human being and animals face new challenges for survival because of climate change. For instance, more frequent and intense drought, storms, heat waves, rising sea levels, melting glaciers, intense rainfalls, and warming oceans can directly harm animals, destroy the environment they live, and wreak havoc on humans livelihood and communities. Scientists around the world have reached an overwhelming consensus that climate change is real and caused primarily by human activity. Respected scientific organizations such as the National Academy of Science, the Intergovernmental Panel on Climate Change (IPCC) and World Meteorological Association (WMA) have all identified climate change as an urgent threat caused by humans that must be addressed.

Greenhouses gases, such as carbon dioxide, trap heat in the atmosphere and regulate our climate. These gases exist naturally, but human add more carbon dioxide by burning fossil fuels for energy (coal, oil, and natural gas) and by clearing forests. Burning fossil fuels, such as coal, oil, and natural gas, to generate energy has the greatest impact on the atmosphere than any other single human activity. Globally, power generation is responsible for about 23 billion tons of CO_2 emissions per year, in excess of 700 tons every second. Coal is especially damaging our atmosphere, releasing 70% more carbon dioxide than natural gas for every unit of energy produced (Inter-governmental Panel on Climate Change IPCC). Greenhouse gases act like a blanket. The thicker the blanket, the warmer our planet becomes. At the same time, oceans are also absorbing some of this extra carbon dioxide, making them more acidic and less hospitable to sea life. As climate change worsens, dangerous weather events are becoming more frequent and severe around the globe. Inhabitants of cities and other places around the world are battling with the effect of climate change, from heat waves and wildfires to coastal storms and flooding. The need for urgent action to address climate change is now indisputable. Thus, the issue of addressing local climate threats has become a major challenge for city planners. These can be achieved by implementing practical measures that improve air quality, protect water supplies and reduce urban flooding. These include; transition toward 100 percent renewable energy and effective management of natural resources such as managing trees in urban areas and other parts of our environment, through timely and accurate acquisition of information on the status, composition, location, extent and structural change of urban forest in order to develop strategies for sustainable development and improve urban environments (Song, 2005; Yang, et al., 2012).

The conventional techniques used for extracting individual trees feature include ground surveying (field inventory) and interpretation of aerial photography. However, these techniques are associated with some constraint such as labour intensive field work and a lot of financial requirement which can be overcome by means of airborne LiDAR (Lang, et al. 2006) and very high resolution digital image datasets. Field surveying generally requires a lot of labour, time and limited by geographical accessibility (Lee, et. al. 2009). Aerial photography does not directly provide 3D information of trees structure (Chen, et al. 2006) and is easily influenced by weather condition and topographical covers (Chen, et al. 2005).

Advancements in remote sensing tools have introduced laser technology which bridges the gap of satellite imagery inability to pass through the trees canopy. This permits fast, cost effective, dense and accurate measurements of underneath trees structure especially, over a very large spatial scale (Rahman, et al. 2015). LiDAR has been found to be useful in the surveying of coniferous urban vegetation (Popescu, et. al. 2007). It has also found to be useful in mapping individual tree stands with more accurate and detailed attributes estimation especially in urban areas which consists of trees of different species, height and health condition (Koch, 2006). The ground-based LiDAR has the ability to acquire a detailed 3D measurement of the tree structure. However, it can only be effective over small geographical extent. Therefore, it suffices to note that integration of airborne LiDAR and multispectral imagery datasets have a great potential to supersede conventional field surveying, as the marrying of two dataset sources is not only capable of extracting individual trees and measuring their metrics but also defining their species types.

1.3 Aim and Objectives

The aim of this research is to extract urban trees from integrated airborne based digital image and LIDAR points cloud datasets. In order to achieve the aim of this research, four objectives have been identified as follows:

- To extract shadow free vegetation area from the digital image.
- To extract 3D information about vegetation areas from integrated processing of shadow free vegetation areas image and LiDAR point cloud datasets.
- To classify the vegetation features.
- To assess accuracy of extracted tree features in order to establish the utility of developed approach.

1.4 Research Question

- How multispectral information from the digital image can be utilized to extract shadow free vegetation areas?
- How the integration of LIDAR and digital image can be useful to estimate 3D-information about vegetation areas?
- Which LIDAR attribute can be used to classify the vegetation?
- How the accuracy of extracted trees can be assessed?

1.5 Scope of Study

The scope of this research covers detection, extraction and classification of urban vegetation features, based on integration use of various attributes of the datasets. This will be achieved using GIS software tools (i.e. ArcGIS and ERDAS imagine) and programming tool (i.e. Python).

For the fulfilment of above objectives, the present study will be carried out over Istanbul city of Turkey with a geographical extent of 41.015137^0 Latitude and 28.979530^0 Longitude.

1.6 Significances of the Study

Information about urban trees provides a means for city planners to better understand trees resources in an urban environment and their numerous values. However, techniques used to evaluate urban trees resources and their possible impacts on the environment have been less explored. Surveying and mapping techniques aid in working out and remodelling environmental policies. They offer data for eventual incorporation of trees in environmental regulation studies, determine how trees affect the urban environment and accordingly enhance environmental quality in urban areas for human health (Jawak, et al. 2013). Urban Tree Canopy (UTC) is an important asset in the urban ecological system as it can reduce the atmospheric heat, runoff and refining atmospheric air condition. Information about existing urban tree canopy serves as a tool for decision makers to better appreciate urban ecosystems and design a number of conservation projects. Furthermore, apt and accurate acquisition of information on the condition, spatial distribution, extent, composition and structural change of urban trees is critical to building up strategies for sustainable development and improve urban ecosystem (Song, 2005; Yang, et al., 2012).

One of the remarkable and promising means to lessen the negative effect of urban growth and its implications is by means of managing trees in urban areas. They are considered as fundamental elements to improve the living conditions of the urban dwellers and to diminish polluting impact as a result of human activities (Song, 2005; Yang, 2012). Trees and green areas help in purifying the atmospheric air by removing pollutants during the transpiration process. They can minimize the issues of urban heat island such as lowering the temperatures by means of transpiration and heat absorption (Pu and Landry, 2012; Weng, et al., 2004). A growing interest has been observed among city planners and stakeholders for a better control and planning of planting and conservation of urban trees. In order to make this effective, the current state of urban trees is required to be mapped using a better approach which is less tedious, cost effective and time saving. Therefore, this research will provide urban planners and decision makers with an innovative method to analyses, evaluate, enhance urban landscape patterns and gain a better understanding of the current composition, spatial distribution, status, extent and structure of trees in urban areas. The extracted information will provide a snapshot of the current composition, spatial distribution, extent and health status of an urban tree which will be useful to city planners to understand how much canopy cover exists, identify new planting, removal, or reforestation opportunities and what locations have the greatest need or potential to maximize benefits of return on investment. It can also help track trends or changes to the urban trees over time and inform future management decisions.

1.7 Chapter organization

This research study includes five chapters, namely; introduction, literature review, methodology, results and analysis and conclusion and recommendations.

Chapter 1: This chapter comprises background of the study, problem statement, aim and objectives, research questions, scope of the study and significance of the study.

Chapter 2: in this chapter, literatures related to the study were reviewed. These include theoretical concept of LiDAR, trees inventory, benefit of LiDAR in trees inventory LiDAR applications in trees inventory, detection and extraction of trees features, vegetation index, integration of airborne digital image and LiDAR datasets and finally, urban trees classification.

Chapter 3: This chapter comprises the general research strategy that outlines the concepts, tools and procedure in which the research task is to be undertaken and, among other things describes the study area and datasets used.

Chapter 4: This chapter exploits and interprets results from analysis of the research findings based on the research methodology established in the previous chapter and also in accordance with the research objectives as stipulated in this study.

Chapter 5: This chapter comprises summary conclusion, recommendations and challenges faced during the study.

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