A STUDY OF TELECOMMUNICATION TOWER VERTICALITY ECCENTRICITY BY USING REFLECTORLESS TOTAL STATION AND UNMANNED AERIAL VEHICLE

TEOH JOSHUA

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Universiti Teknologi Malaysia

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DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

An aerial survey utilising a drone or other unmanned aerial vehicle (UAV) can give a quick and effective way to collect data across tall structures in a short amount of time. Inspection surveys using UAV enable safer access to assets that are hazardous, dangerous, or difficult to access, such as high-voltage powerlines and towers, flare stacks on and offshore, and high-rise structures. UAV inspections lessen the risk to employees by placing the operator in a safer setting than would be the case if the same operation were done manually. The number of visits and workers necessary to the site is reduced by providing a selection of products that can be shared and seen several times in the office by engineers, making the works safer. UAVs were created as a result of low-altitude photogrammetric mapping to improve aerial photography accuracy and image resolution. As a result, the goal of this research is to use a UAV and a reflectorless total station to manage the verticality eccentricity of a telecommunication tower. Before taking an aerial photograph using a UAV, several factors were carefully addressed, including image resolution, flying height, flying radius, and speed to fly on the site area to eliminate natural errors. Before merging and defining the different of the error based on the eccentricity, a systematic produce was carried out, for example, reflectorless total station and UAV survey. The reflectorless total station will be used to acquire the vertical eccentricity of the tower drawing, which will then be examined using AutoCAD software. The UAV will provide digital photographs, which will be processed using Pix4D software. The final stage will be to define the 3D model once all of the data has been analysed. The surveyor can define the structure of the tower in Pix4D software by exporting the polyline to AutoCAD software. As a result, surveyors can calculate the verticality eccentricity based on the tower's ground platform and analytical mistakes for each tier.

ABSTRAK

Tinjauan udara menggunakan drone atau kenderaan udara tanpa pemandu (UAV) boleh memberikan cara yang cepat dan berkesan untuk mengumpul data merentas struktur tinggi dalam masa yang singkat. Tinjauan pemeriksaan menggunakan UAV membolehkan akses yang lebih selamat kepada aset yang berbahaya atau sukar diakses, seperti talian kuasa dan menara voltan tinggi, timbunan suar di atas dan luar pesisir serta struktur bertingkat tinggi. Pemeriksaan UAV mengurangkan risiko kepada pekerja dengan meletakkan pengendali dalam keadaan yang lebih selamat berbanding operasi yang sama tetapi dilakukan secara manual. Bilangan pekerja dan lawatan yang diperlukan ke tapak dikurangkan dengan menyediakan pilihan produk yang boleh dikongsi dan dilihat beberapa kali di pejabat oleh jurutera, menjadikan kerja lebih selamat. UAV telah dicipta, hasil daripada pemetaan fotogrametri altitud rendah, untuk meningkatkan ketepatan fotografi udara dan resolusi imej. Matlamat penyelidikan ini adalah untuk menggunakan UAV dan stesen penuh untuk menguruskan kesipian menegak menara telekomunikasi. Sebelum mengambil gambar udara menggunakan UAV, beberapa faktor telah ditangani dengan teliti, termasuk resolusi imej, ketinggian terbang, jejari terbang dan kelajuan terbang di kawasan tapak untuk menghapuskan ralat semula jadi. Sebelum menggabungkan dan mentakrifkan perbezaan ralat berdasarkan kesipian, hasil yang sistematik telah dijalankan, contohnya, stesen penuh dan tinjauan UAV. Stesen penuh akan digunakan untuk memperoleh kesipian menegak lukisan menara, yang kemudiannya akan diperiksa menggunakan perisian AutoCAD. UAV akan menyediakan gambar digital, yang akan diproses menggunakan perisian Pix4D. Peringkat terakhir adalah untuk menentukan model 3D sebaik sahaja semua data telah dianalisis. Juruukur boleh menentukan struktur menara dalam perisian Pix4D dengan mengeksport polyline ke perisian AutoCAD. Hasilnya, juruukur boleh mengira kesipian menegak berdasarkan platform tanah menara dan kesilapan analisis untuk setiap peringkat.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Unmanned aerial vehicle (UAV) are increasingly being used to inspect industrial structures, not only because of the low cost, speed, and efficiency of the method, but also because of the lower risk involved when compared to traditional inspection methods such as climbing up to the tower and using the plumb-bob technique to check the tower's eccentricity and verticality.

In recent years, a reflectorless total station has become one of the tools for surveying telecommunication towers by measuring distances to any light-colored object and displaying the coordinates of specified spots. Reflectorless total station instruments, such as the Leica TS06PLUS, can be advantageously utilised for localized-type surveys requiring precision figures of up to 10 mm in range of 80 m and 100 m, with the accuracy figures obtained being mostly reliant on the kind of reflecting surface.

Many fieldworks have made use of an UAV. The reason for this is because of the advantages of the technology has brought into professionals, such as shorter turnaround times and lower costs. To minimise extra problems, surveyors usually aim to spend as little time as possible in the field. The objective of this project is to determine the accuracy of the results obtained by the UAV using the photogrammetry technique, as well as if the reflectorless total station approach is a reliable way for determining the verticality eccentricity of a telecommunication tower.

A generic aircraft, according to the UVS International (F. Remondino, 2011) definition, is intended to operate dependent on the number of human pilots onboard. Although the word UAV is widely used in the geomatics community, other terminology such as remote controlled helicopter (RCH), remotely piloted vehicle (RPV), remotely operated aircraft (ROA), and unmanned vehicle system (UVS) are also often used. UVS International divides UAVs into three categories based on their weight range, size, and flying attitude, which are mentioned below:

- Micro, mini, near, brief, medium-range, medium-range endurance, low altitude deep penetration, low altitude long endurance, and medium altitude long endurance systems are all examples of tactical UAVs. The mass varies from a few kilogrammes to 1,1000 kilogrammes, the range from a few kilometres to 500 kilometres, the flying altitude varies from a few hundred metres to 5 kilometres, and the endurance varies from a few minutes to 2-3 days.

- High altitude long endurance, exo-stratospheric system, and stratospheric strategic UAVs will be able to fly higher than 20,000m altitude and also have a 2-4 day endurance.

Unmanned combat autonomous vehicles, as well as deadly and decoy systems, are examples of UAV special duties.

1.2 Problem Statement

The reflectorless total station's results production has always been exact in the field. Surveyors, on the other hand, will need extra time in the project to complete a full detail mapping of the road alignment, structures, and fence. To clarify, the AutoCAD software drawing of the reflectorless total station simply shows the 3D telecommunication tower layer. One of the reasons is that reflectorless data simply provides the tower's eccentricity coordinates, which are derived by seeing four corners of the tower construction. In this instance, the data will not be readily visible in the area surrounding the tower.

As a result, the recommended technique to eliminate the present problem is the UAV. The ability of a UAV to capture digital images from the air and surrounding of the tower as photogrammetry data and create a 3D model is one of its features. A spiral flight with a fixed radius around the tower is another feature of UAVs. Because UAV delivers accurate, dense 3D point cloud that concentrates on the top rad centre mounts, wireless-panel type antennas, and related mounts, the suggested method is satisfying by aligning at the detail drawing and short time frame. Using the high-resolution photos and the point cloud, the project engineer measured the mount brackets.

One of the reasons why UAV is recommended as a technology for carrying out telecommunication tower work is that some telecommunication tower regions are secured with security guards for safety reasons. Telecommunication towers are constructed to broadcast mobile signals throughout an area, and the technology installed on these towers is costly. The telecommunication tower location will be fenced and inaccessible to the general public. By employing a UAV, a surveyor can fly around a telecommunication tower without having to enter the tower area, and some telecommunication towers do not have an access road, making it impossible to survey the telecommunication tower using a reflectorless total station.

1.3 Objectives of Study

The objective of this study is to determine the accuracy of the results obtained by using UAV and compare the results with the reflectorless total station approach of a telecommunication tower. In order to fulfil the objectives of this study, the following are the study's objectives, which have been defined to guarantee that the study is carried out according to plan and within the expected timeframe:

i. To observe and analyse the UAV photogrammetry data in order to produce a 3D model and digitizing the corner of the telecommunication tower for the verticality eccentricity calculation.

ii. To construct and digitized a verticality eccentricity drawing based on a telecommunication tower from the UAV photogrammetry data and reflectorless total station data.

iii. To validate the quality and reliability of UAV point clouds and reflectorless total station data.

1.4 Scope of Study

The research's scope is determined by a number of factors, including data collecting, study area, software to be utilised, equipment, and, finally, data analysis. This research focuses on using UAV to examine a telecommunication tower. In general, surveyors utilised a reflectorless total station to compute the tower movement by measuring the four corners of the tower by each layer of the telecommunication tower structure. A UAV will be used in this investigation to collect photogrammetry data and provide an accurate 3D point cloud that concentrates on the surrounding of the telecommunication tower.

The study will take place on a celcom company near Indera Mahkota, Kuantan, Malaysia. In general, the chosen place is ideal for doing the activity since it is less constraint such as congested and has less cars going around it.

For data collection in digital images format, a UAV is employed. To assure that the data collected covers the whole research region, a mission flight plan and manual spiral flight plan was developed. The digital images were captured in two ways where at a fixed height using a digital camera placed in the UAV and fixed radius and different height surrounding the telecommunication tower.

A reflectorless total station is used to measure distances up to a few hundreds of meters to any object that is adequately bright in colour. Surveyors are unable to climb to the top of the structure and put the prism in order to measure the distance due to the sheer height. This is why the use of a reflectorless total station is necessary in this research. Although, this information will be collected by the total station, and the verticality eccentricity of the tower will be digitized and calculate manually in the AutoCAD software. In this investigation, two key pieces of equipment will be used: a reflectorless total station (LEICA TS06 Plus) and a DJI Phantom 4 Professional (UAV) (see Figure 1.1).

Figure 1. 1 Leica TS06+ (Reflectorless) and DJI Phantom 4 Pro (UAV)

The vertical eccentricity of the tower sketch will be calculated using a reflectorless total station and examined with AutoCAD software. The UAV will provide digital images, which will be processed using Pix4D software. The final stage will be generating the 3D point cloud from all of the photos taken by the UAV and processed by the Pix4D software once all of the data has been processed. The surveyor can specify the construction of the tower in Pix4D software by exporting the polyline after digitized and the 3D point cloud to AutoCAD. As a result, surveyors may calculate the verticality eccentricity based on the tower's ground platform and analytical mistakes for each tier.

1.5 Significance of study

The significance of the study's findings and the significant impact that may be expected:

i. To introduce UAV as one of the approaches for gathering photos of telecommunication towers.

ii. Create a new technology that save time and money.

iii. Demonstrate that a UAV may be used to conduct a tower verticality eccentricity study.

iv. To create a more thorough and precise drawing that will assist clients and future users to better comprehend the designs.

v. To check the UAV's accuracy using the standard reflectorless total station approach.

1.6 Thesis Overview

The background, objectives of study, problem statement and scope of the study connected to the topic of 'telecommunication tower verticality eccentricity by employing reflectorless total station and unmanned aerial vehicle' are briefly discussed in Chapter One.

The core element of the research is explained in Chapter Two, which instils with the notion of the UAV system and refelctorless total station system, as well as various theories and applications used in this study. This chapter examines an innovative research study on UAV systems and utility surveys, as well as some valuable references.

The methodological research is covered in Chapter Three. It consists of some field techniques, data collecting, and data processing in order to validate the correctness of the survey detail accuracy band table. This allows study to investigate into the possibilities of using the data from the UAV. This chapter will critically examine the study's details, beginning with data collecting and ending with data processing.

The results of the study will be covered in Chapter four. The results and interpretation of the results will be displayed using tables and graphs. In addition, the outcomes of different UAV photogrammetry in terms of DSM and Orthomosaic will be explained in this chapter. The use of a UAV in conjunction with a reflectorless total station to check accuracy is described in depth. All UAV and reflectorless total station calculations will be shown and explained.

The last chapter of the thesis summarises the thesis's remarks and suggestions, as well as identifies which elements of the study should be improved further. In addition, this chapter focuses primarily on addressing the study objectives and achieving the UAV method's goals.

REFERENCES

Allerin. (2013). 10 stunning applications of drone technology. Application development | Big data| IoT | Digital Business | Cloud. https://www.allerin.com/blog/10-stunning-applications-of-drone-technology

Australian DRONE magazine. (2016). Drone types: Multi-rotor vs fixed-wing vs single rotor vs hybrid VTOL. AUAV. https://www.auav.com.au/articles/drone-types/

Caliper Mapping and Transportation Glossary. (n.d.). What is a DEM - Digital elevation model definition. Caliper - Mapping Software, GIS, and Transportation Software. https://www.caliper.com/glossary/what-is-a-digital-elevation-model-dem.htm

Civil engineering notes. (2021). Total station : Advantages & features. Civil Engineering Notes. https://civilengineeringnotes.com/total-station/

Dai, F., Feng, Y. & Hough, R. Photogrammetric error sources and impacts on modeling and surveying in construction engineering applications. Vis. in Eng. 2, 2 (2014). https://doi.org/10.1186/2213-7459-2-2

Daly. (2021). 3 reasons you should use drones for cell tower inspections. Consortiq. https://consortiq.com/3-reasons-you-should-use-drones-for-cell-tower-inspections/

Demirel, A. S. (no date) 'Two Functional Software for Internal Use ; Flight Planning and Presenting of Digital Orthophotos', Main.

Drone Nerds. (2019). Tower surveying with a drone. Enterprise Drone Solutions. https://enterprise.dronenerds.com/tower-surveying-with-a-drone/

Drone Pilot Ground School. (2020). A drone pilot's guide to surveying a tower. https://www.dronepilotgroundschool.com/tower-surveying/

DroneDeploy. (2017). Seven ways to improve the accuracy of your drone maps. Medium. https://medium.com/aerial-acuity/seven-ways-to-improve-the-accuracy-of-your-drone-maps-9d3161f05956

Engineer Supply. (n.d.). Please wait... Please Wait... | Cloudflare. https://www.engineersupply.com/Can-a-drone-survey-replace-the-total-station.aspx#:~:text=A%20total%20station%20can%20only,may%20not%20be%20limited%20to%3A&text=Point%20cloud

Equinoxs Drones. (n.d.). 10 major pros & cons of unmanned aerial Vehicle(UAV) drones. Drone companies in India | Drone Survey, Drone Services, UAV, Mapping. https://www.equinoxsdrones.com/blog/10-major-pros-cons-of-unmanned-aerial-vehicle-uav-drones

FIZZ Marketing & Communicatie. (n.d.). 5 tips to improve accuracy in your drone mapping projects. Geo-matching | Your Product Platform for Surveying, Positioning and Machine Guidance. https://geo-matching.com/content/5-tips-to-improve-accuracy-in-your-drone-mapping-projects

Jae Woo Park & Dong Jun Yeom (2022) Method for establishing ground control points to realize UAV-based precision digital maps of earthwork sites, Journal of Asian Architecture and Building Engineering, 21:1, 110-119, DOI: 10.1080/13467581.2020.1869023

Millman National Land Services. (2021). What is a cell tower and how does a cell tower work? Millman Land. https://millmanland.com/company-news/what-is-a-cell-tower-and-how-does-a-cell-tower-work/

Murison, M. (2021). Surveying drones vs total stations: Which type of surveying projects are drones ideal for? DJI – Insights Blog. https://enterprise-insights.dji.com/blog/when-to-use-surveying-drones

Pix4d. (2016). Cell tower inspection with drone for new antenna Mount. Pix4D. https://www.pix4d.com/blog/cell-tower-drone-inspection-antenna-mount

Raju. (2016). Analysis and design of telecommunication tower. Share and Discover Knowledge on SlideShare. https://www.slideshare.net/Rohithasangaraju/analysis-and-design-of-telecommunication-tower?next_slideshow=63667980

Remondino, F., Barazzetti, L., Nex, F., Scaioni, M. and Sarazzi, D. (2011) 'Annals of Surgery 2009 Nguyen', XXXVIII(September), pp. 14–16.

RF Wireless World. (n.d.). Cell phone tower basics | cell phone tower types,components. RF Wireless Vendors and Resources | RF Wireless World. https://www.rfwireless-world.com/Tutorials/cell-phone-tower-basics-and-cell-phone-tower-types.html

Rokubun. (2021). Drone photogrammetry flight planning recomendations. https://www.rokubun.cat/drone-photogrammetry-flight-planning/

Scia Engineer. (n.d.). Accidental eccentricity. https://help.scia.net/14.0/en/sr/seismic_analysis_of_buildings_05_accidental_eccentricity.htm

SHM Telecom. (2014). SHM telecom towers. ESA Business Applications. https://business.esa.int/projects/shm-telecom-towers

Sholarin, E. A. and Awange, J. L. (2015) 'Photogrammetry', Environmental Science and Engineering (Subseries: Environmental Science), (9783319276496), pp. 213–230.

Singh. (n.d.). Applications of UAV(Drone) data. Satellite Imagery and Geospatial Services | SATPALDA. https://www.satpalda.com/blogs/applications-of-uavdrone-data

Singh. (n.d.). Concepts of photogrammetry. Satellite Imagery and Geospatial Services | SATPALDA. https://www.satpalda.com/blogs/concepts-of-photogrammetry

Sircle. (2021). Verticality survey. https://sircleuk.com/services/building-surveys/verticality-survey/

Telecoms Infrastructure. (2020). Drones for tower inspections and optimization. Telecoms Infrastructure Blog. https://www.telecomsinfrastructure.com/2020/07/drones-for-tower-inspections-and.html

The Constructor. (2018). Methods to check verticality of structure during building construction. https://theconstructor.org/construction/methods-check-structure-verticality-building/21676/

Tiger Supplies. (n.d.). AdirPro GFZ3 diagonal eyepiece for Leica total stations & auto levels tiger supplies. Surveying Equipment, Drafting & Art Supplies Emporium for Engineer and Architects Tiger Supplies. https://www.tigersupplies.com/Products/GFZ3-Diagonal-Eyepiece-for-Leica-Total-Stations-and-Auto-Levels__ADI790-14.aspx