An Innovative 3D Interactive Platform Sourcing Geographic Information Combining Operating Photogrammetry Airborne LiDAR and Mobile Measurement System

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1. INTRODUCTION

A proliferation of new topographic and surface sensing technologies have complicated the interpolation of data from disparate sources. Photogrammetry provides spatial information from distances above ground level, while the acoustic and light detection and ranging radar (LiDAR) and Mobile Measurement System (MMS) are commonly used at the ground level. The integration of multiple methods during the post-processing stage not only is trvial and time-comsuming but also requires significant experience and reliable standard procedures. As the intensity and frequencies of natural disasters increase at an acelerating speed, government authorities, rescue operation teams and engineers demand instantaneous tools facilitating commincation among stakeholders when makingdecisions.

To minimize human error in the process and to expedite the technology fusion, Strong JP International Co. launched an internal research project, developed a 3D interactive plateform consisting of SkylineGlobe, photogrammetry, and laser scanning technology. The goal aims at establishing an information management plateform storing 2D and 3D spatial data management system while end users review and retrieve measurable information in an interactive manner. The plateform integrates and standardizes post-processing procedures based on SkylineGlobe, a 3D interactive GIS containing large volume of spatial information collaboratively collected from operating photogrammetry, airborne LiDAR and MMS. This robust automation approach adopted cloud comuting machinsim. It has been proven mature in numerous cases. A 3D working environment provides a new instrument in spatial management, urban planning, and long-term ecological monitoring in various landscapes on the Earth's surface.

2. INTEGRATION OF SOFTWARE AND HARDWARE

2.1 SkylineGlobe

The foundation of the framework, SkylineGlobe is a 3D earth visualization commercial package developed by Skyline Software Systems, Inc. in Herndon, Virginia, U.S. The SkylineGlobe suite of interactive applications allows end users to build, view, query and analyze customized, virtual 3D landscapes. The 3D view is created by merging aerial and satellite photography and imagery, terrain elevation data, and other 2D and 3D information sources, including geospatial data layers. A unique function allow "on the fly" data fusion from disparate and distributed sources without data pre-processing, allowing end users to keep 3D working environment as current and relevant as the underlying data. Strong JP International Co. Deploys the web based application with self-invented Application Programming Interface (API) to customize a seamless 3D interface allowing stakeholders to operate and review 3D outcome from a desktop at remote locations.

2.2 LiDAR Riegl Q680i

As shown in Figure 1, the RIEGL LMS-Q680i is a long-range airborne laser scanner making use of a powerful laser source, multiple time around (MTA) processing, and one-of-the-kind digital full waveform analysis. The full waveform enhances data acquisition by continuosly collecting reflecting waves as shown in Figure 2. This combination allows the operation at varying flight altitudes suitable for aerial survey of complex terrain. Currently, RIEGL LMS-Q680i is the most popular module surpassing its competitors. It has been proven an effective tool that dramatically improves the efficiency of the current workflow used by power line companies. It was also revealed that using a fixed wing aircraft and high resolution RIEGL LMS-Q680i can substantially lower operating costs while delivering incredibly dense and accurate full waveform point cloud data.

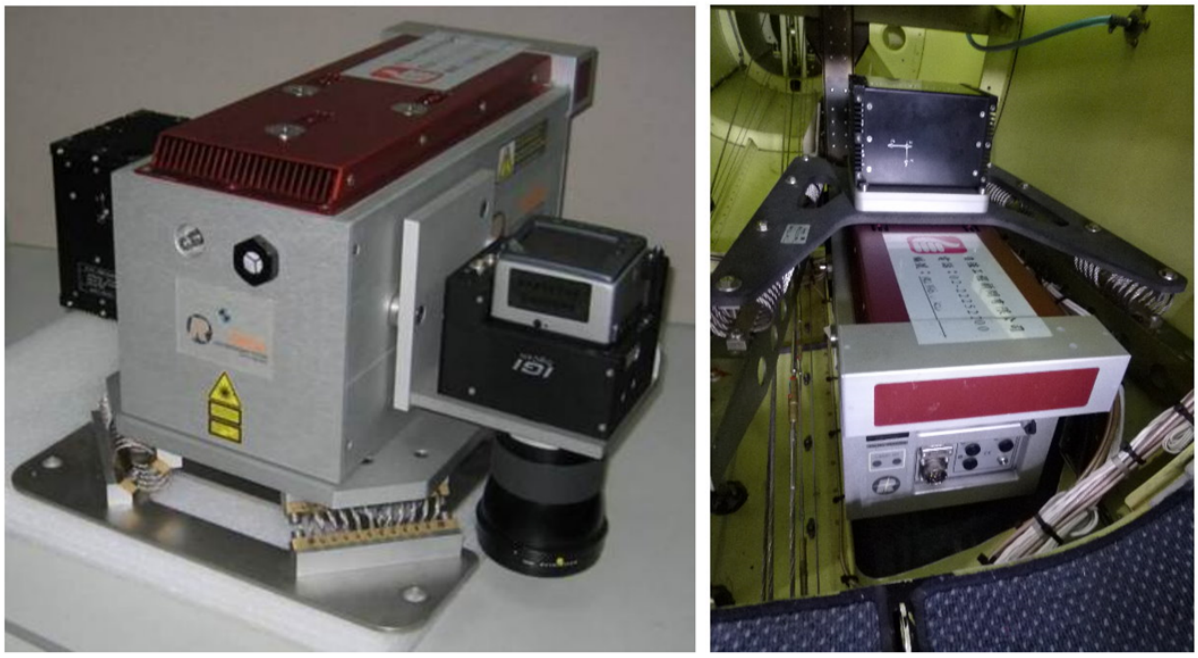


Figure 1. Pictures of RIEGL LMS-Q680i

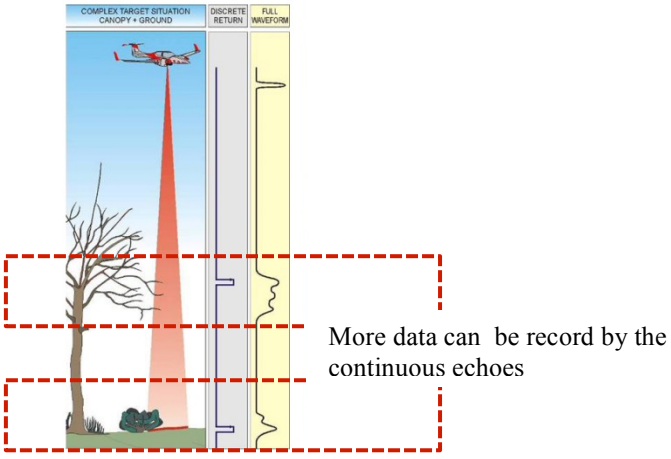


Figure 2. An Illustration of full waveform (www.riegl.com)

2.3 UltraCam XP

An award-winning digital aerial camera, UltraCam XP is unique in its monolithic stitching capability. Microsoft Corporation and its subsidiary Vexcel Imaging, GmbH developed this innovative technology in Photogrammetry. The UltraCamXp features a proprietary, high-performance, high-resolution lens system allowing sensors to deliver the ground sample distance (GSD) at various flight altitudes. It has completed the USGS Sensor Type Certification Process demonstrating that the UltraCamXp is capable of providing quality, consistent image data to support infrastructure projects at the performance level specified in the USGS sensor type certification report. Figure 3 shows photos of UltraCam XP mounted on one of Strong JP International Corporate planes.

Figure 3. A Mounted UltraCam XP on Company Aircraft

2.4 Riegl 250 mobile LiDAR

The founder of RIEGL, Dr. Johannes Riegl pioneered development of the essential circuitry of a semiconductor laser transmitter in 1970s. Ever since the first miniaturized laser distance meters was developed in 1972, Riegl Laser Measurement Systems (LMS) has been the leader in developing airborne, terrestrial and industrial instruments. In 2009, the company entered the mobile scanning arena, and debuted the VMX-250 to the world at Intergeo in Karlsruhe. Riegl 250 mobile LiDAR shortens the schedule and improves the safty of surveyors. A typical highway project employing traditional surveying methods may take a week, while exposing survey crews to traffic and dangerous conditions. The same survey collected with mobile scanning equipment takes less than two hours and provide more information than a survey crew could ever collect in a month. More importantly, no one will be exposed to potentially hazardous working conditions. Figure 4 shows a VMX-250 mounted on a automobile.

Figure 4. A Photo of Mobile Measurement System (MMS)

2.5 Post Processing

During the post-processing of the images and digital information, the integration of 2D and 3D data obtained from multiple methods requires significant experience and programming. Also, data with different densities must be interpolated and modeled to produce proper resolution within a reliable system. The research team has exhausted sofeware and even pregrammed to identify the coherence between images when using limited high-resolution information. Finally, the overall cloud computing framework features several key components written in a common server-side programming language and built-in API on SkylineGlobe. The team designed and conducted numersous pilot studies in different scales and terrains, followed by cross validation, and then compared the SkylineGlobe model sampled data with the actual field measured data. The pilot study confirmed the system is an adequate approach with satisfactory accuracy. The schedule and cost saving are remarkable. In one the cases, the final precise ground elevation profile combines high resolution photogrammetry images at the scale of 10 cm Ground Sample Distance (GSD) and high density point cloud. The SkylineGlobe generate Digital Elevation Model (DEM) of 1 m raster, and the precision level reaches up to 10 cm in horizontal and vertical directions, normally within 30cm average. This paper also includes one case in detail as follows.

3. CASE STUDY

3.1 Hualien Coastline Topographical Observation Project

Hualien County is the largest county in Taiwan in terms of area, and is located on the mountainous eastern coast of Taiwan facing the Pacific Ocean. Hualien County is famous for tourism, its 175 km coastline possesses well suited scenery for bikers. The Water Resources Agency, Ministry of Economic Affairs, Taiwan started shoreline preservation for decades. The project scope includes long-term monitoring of the coastline erosion. The scale of the project, the operating time frame for the integration of multiple technologies, and the demand from a variety of stakholders makes the interactive SkylineGlobe plus laser technology the only feasible option. The observation records can be traced back to 1986. To quantify the topographical change with respect to time, project team set up observatory stations to fully capture the magntude of changes in a timely manner. The coastal protection investigation in Hualien requires the decision maker to explorre the cause of, and the need to mitigate the erosion associated problem. The Strong JP International Co. Team offered a total solution on

the data collection, providing bases for research institutions to conduct hydrologic experiments and for consulting engineeris to design and construct seawalls. In this project, airborne LiDAR and terrestrial LiDAR were used for acquiring spatial data. The massive volume of data has been processed and stored on the SkylineGlobe. Finally, the governing authority analyzed the information in 3D working environment and demonstrated the outcome when communicating to various stakeholders.

Figure 5 shows the flight plan on four sampled coastline at 6 km, 4 km, 2 km and 2.2 km, respectively. The targetted areas are marked in red boxes. LiDAR was used to survey above ground level, while single-beam echo sounder (SBES) and multi-beam echo sounder (MBES) were used below water or sea level.

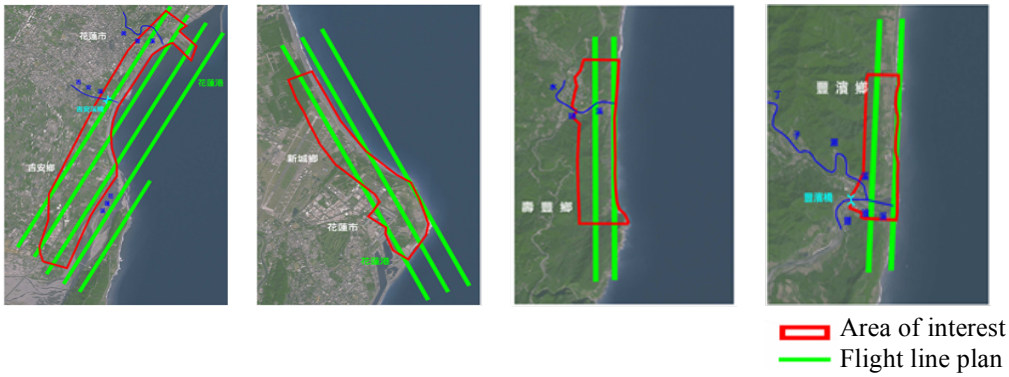
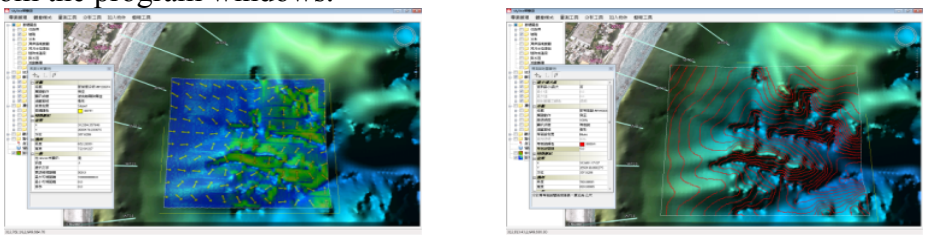
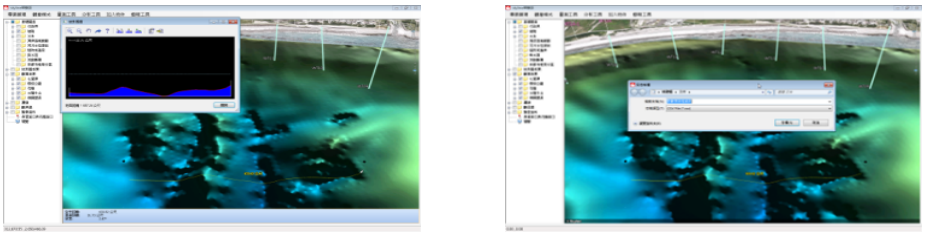


Figure 5. Flight plan on targetted areas

Through minimization of local error variance and reproduction of local roughness characteristics into SkylineGlobe, high resolution topography obtained from aerial LiDAR were included. The fracture surface topography process is improved by cross validation cycling and finally Skyline offers a 3D interactive spatial model. End users may choose to enter other geographic information at later stage, such as: transportation, geology, hydrology, land use, and urban planning. During the planning and detail design stage, engineers may select target positions, turn around, zoom in, zoom out, draw contourlines, and take measurement at any point of interest to visualize slope directions and to cut cross sections on a profile. The system also provides optional functions for output. Figure 6 shows several outcome from the program windows.



Slope Directions Contour Lines



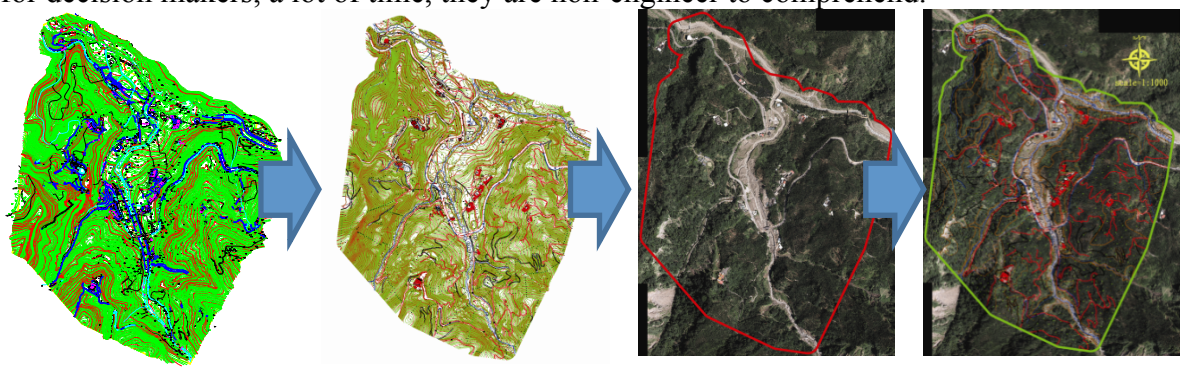
Cross Sections Interactive Windows

Figure 6. SkylineGlobe analyzing windows

Through customized window, a 3D model along the Hualien Coastline enables end users to explore and to retrieve data at various layers. The final objective of the Hualien Coastline Topographical Observation Project is quantified and the success on execution of the shoreline preservation is visible. Decision makers at various levels of government authority conducted well received workshops and public hearing by using the system. The coordination among stakeholders became smooth because of the visualization greatly improve the communication.

4. DISCUSSION AND LESSONS LEARNED

There are at least four dominant aspects when consider the feasibility and applicability using the system in a project. They are: planning, operation schedule, cost, and quality requirements. The sample case was made possible becasue the team had a solid work plan with regard to equipment mobilization and coordination. Taking aerial photos requires prior permits from the central government and notification to the coastguard. The planning on the automobile and airplane routes is the key to a successful saving and efficiency. Secondly, the risks associated with conventional survey at remote area offen threaten the survey crew. Not only the risk-free operation minimizes the concern to safety, the conentional lengthy operation is greatly reduced. The duration for a traditional digital ground survey of 130 hectors took 5 consecutive months. The team deployed airplane missions for photogrammetry and Airborne LiDAR twice in 3 months interval. Refer to Figure 7, the average deviation of precision is less than 10 cm, sometimes less than 5 cm. Lastly, SkylineGlobe in junction with laser scanning technology also demonstrates on a 3D working environment not only increases efficiency superseding conventional engineering survey methods but also enhances the level of accuracy. The instantenous, interactive tool enables end users to vidualize 3D images when communicating to stakeholders. Normally large volume of spatial information is intengible for decision makers, a lot of time, they are non-engineer to comprehend.



Topographic map of traditional digital ground survey	Topographic map of Photogrammetry	Ortho photo	Lapping ortho photo on topographic map

Figure 7. The results compared among ground survey and ortho photos

5. SUMMARY

There have been several calibration, compatibility and cost issues related to the integration and interpretation of various surveyed techniques by photogrammetry, airborne LiDAR and MMS with differing resolution or man-made error from human operation. Fusion of multi-technologies and obstacles in remote areas frequently raise concerns about the proper training and personal safety of field investigators. To produce thorough ground profiles and configuration of solid objects in a conventional manner, surveying crews sometimes risk their lives to physically penetrate difficult areas and traffic to conduct surveying through direct contact. Moreover, timing is crucial and the data collected must be thorough for the decision makers to make a timely, comprehensive analysis. It is desirable to measure the overall spatial information in a short period of time by adopting functions validated through a rich data bank and taking advantage of the speed of the internet. The SkylineGlobe 3D Interactive Platform shortened the operational path, streamlined the process, and pushed the envelope of what cloud computing can offer. This paper reports the development of an innovative system and illustrates a real-world example. Finally the knowledge gained and lessons learned are extremely valuable. This system is applicable to a wide array of applications, such as: digital archive, urban planning, tourism, real-time imagery, security monitoring, disaster relief exercise, cadastral administration, and early flood warning.

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BIOGRAPHICAL NOTES

Mr. Kong Hin Yew received the Master of Science Degree in Remote Sensing and Geographical Information Systems at Universiti Putra Malaysia, Serdang, Selangor, Malaysia. He serves as general manager to Strong JP International Co..

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