Teaching Terrestrial Laser Scanning for Spatial Data Collection and Applications - Experiential Learning as a Tool to Enhance the Development of Higher Level Graduate Capabilities

Xiaoye Liu[a], Zhenyu Zhang[a] and Marita Basson[a]
School of Civil Engineering and Surveying, University of Southern Queensland, Australia[a]
Corresponding Author's Email: Xiaoye.liu@usq.edu.au

Introduction

Terrestrial laser scanning (TLS) is one of the most effective and efficient means of spatial data collection for a wide range of applications, including engineering applications. It is an active remote sensing technology that enables the collection of high-density and high-accuracy 3D point cloud data in a short period of time. Over the last decade, TLS has become one of the most commonly used technologies in surveying and spatial science (Zhang, 2017), but has also found its home in structural and civil engineering in projects like airport layout optimisation, coastline monitoring and water-risk assessment (Berenyi et al., 2010; Hinks et al., 2013); building information modelling (BIM) (Randall, 2011); construction engineering, monitoring and management (Mukupa et al., 2016; Pejić, 2013); production system engineering (Berglund et al., 2016); volume estimation for mining (Hinks et al., 2013) and geological engineering (Nguyen et al., 2011). The relationship between TLS and the various engineering disciplines cannot be disputed. The high levels of accuracy required of data inputs in the engineering environment thus heavily relies on the surveyor who captures the 3D data (Berglund et al., 2016), which has implications for tertiary institutions teaching surveying.

The significant progress in the field of precise measurements and its instrumentation poses the question how these advances are conveyed from the field of knowledge to students, as universities are expected to educate students on the latest developments in order to ensure employability and job-readiness of students (Hejmanowska et al., 2015). Universities providing education in surveying need to ponder not only surveying curriculum design but also the design of individual courses to ensure that students are competent users of cutting edge technology such as TLS, given the high-liability application of the data that they will provide.

The University of Southern Queensland (USQ) is one of the leading providers of tertiary education in civil engineering and construction management, and is the only university in Queensland providing both undergraduate and graduate qualifications in surveying. These qualifications can be gained via online, blended and on-campus modes of education. Responding to the calls from industry for faster, safer and more accurate alternatives to traditional surveying methods, the School of Civil Engineering and Surveying has strived to improve the teaching of efficient spatial data collection methods over the last decade (Zhang & Liu, 2019). Since 2008, with the acquisition of our first terrestrial laser scanner, Leica ScanStation 2, TLS has been introduced as part of the remote sensing curriculum in a both a third year course, Photogrammetry and Remote Sensing, as well as a fourth year course, Advanced Surveying, as well as research topics on TLS in our capstone research courses. To breach the divide that often exists between academia and practice with the adoption of new technologies, a combined practitioner/academic instructed workshop was designed to both educate students on the theory underpinning TLS knowledge and to improve students' practical skills. This workshop has been part of a practice course since 2012. The aim of the one-day workshop is to enable students to demonstrate an understanding of the principle of TLS, describe the categories of terrestrial laser scanners, explain the error sources in TLS, understand the general procedure of a laser scanning project, perform laser scanning field work using our FARO 3D Focus laser scanner, process laser scanning data and produce a cleaned point cloud data for 3D building modelling. The fourth year course, Advanced Surveying, provided the opportunity to scaffold the acquisition of knowledge on LTS by providing higher level instruction and requiring higher practical skills levels in TLS. The latter course includes error analysis, project planning, field work procedure, data processing and applications of TLS (Zhang, 2017).

In the early part of this paper, we presented the field of TLS, and its applications in the wide variety of engineering disciplines. We also highlighted the necessity for high levels of accuracy in the high-liability engineering environment, the significant advances in TLS in the past decade and the necessity of ensuring that students are competent users of such technology. We then briefly described the current instruction of, as well as research opportunities on TLS for surveying students in the School of Civil Engineering and Surveying at the University of Southern Queensland, Australia. The next section will deal with the pedagogical approaches adopted to teach TLS.

Experiential learning in a blended learning environment as a tool to enhance graduate attributes

Higher level graduate attributes are very important for surveying students, especially considering the demands of industry for greater job readiness in an industry suffering a skills shortage and an aging workforce. Given that up to 85 percent of our students are online, mature aged students, many of whom are employed either in a part-time or full-time capacity, it poses a conundrum on how to ensure that students acquire those higher level graduate attributes. The answer appeared to lie in adopting an experiential learning paradigm for the education of these students. Experiential learning is a four-stage cycle, where the first stage is providing experiences that allow the participants to observe, the second stage allows them to review and reflect on what they have learned, the third stage gives them the opportunity to critically reflect so that they can link their experiences to either the theoretical knowledge they have acquired or their previous experiences, and the last stage is active experimentation. It is also a paradigm where students are seen to bring their own knowledge, ideas, beliefs and practices to the learning process (Bartle, 2015; Seaman et al., 2017), a paradigm that suits the characteristics of our diverse student cohort well.

TLS in a practice course and an academic course

Experiential learning is a continuous process (Fenwick, 2000). Both theory and practice are conceptualised and reconceptualised to ensure a deepening spiral of student understanding (Bartle, 2015; Kuk & Holst, 2018). The TLS workshop in the third year presents the starting point for knowledge on TLS. The workshop includes a short lecture and a demonstration of a laser scanner in operation which represents the first stage (opportunity to observe); subsequently students are provided with instructions for field work to prepare for actual field work (opportunity to reflect on what they have learned as well as critically linking their experiences to their theoretical knowledge or any experience they may have in surveying); and the last stage is laser scanning field work and data processing (active experimentation). Figure 1 shows the field work setup and the artefact produced after processing the data obtained during the fieldwork.

To provide greater authenticity to the learning experiences industry engagement has been employed to provide a bridge between knowledge and skill gaps as it can contribute further to graduates’ learning outcomes and employability (Male & King, 2019). Professionals from industry present new developments in laser scanning technology and demonstrate industry application examples in the TLS workshop. Industry engagement shows students the importance of life-long learning (another higher level graduate attribute resulting from experiential learning) as ongoing innovation and technology trends are presented and explained to the students. One of the prime responsibilities of education is to prepare graduates for employment in increasingly complex and diverse situations (King et al., 2015). Industry engagement also provided opportunities and facilities to improve the learning and teaching activities for students. For example, through industry engagement, one of the 3D Laser Scanning Consultant Company provided USQ with a free license for I-Site Studio and I-Site Point Studio software, an alternative desktop tool for our students to process large point cloud data from laser scanning.

Figure 1: Field work in laser scanning and produced point cloud in TLS workshop

The reflection part of the spiral of student learning was deepened by the opportunity for the students to reflect on the workshop during a student survey. The survey results provided valuable information about students' experience as well as expectations. The 2017 survey results (n = 46) revealed that students found the workshop valuable, with an average evaluation score for the workshop being 8.8 out of 10. The survey data also showed that 39% of the students have used the laser scanners in their workplaces before attending the workshop - a considerable change compared with 2012 when very few students had any experience with the laser scanners. The survey data also confirmed that there has been increasing interest in the applications of TLS in the surveying and related professions, such as engineering, over the last five years. Students who had some kind experience in the use of laser scanners reported strong motivation to improve their understanding of TLS, and to enhance their practical skills such as field work and data processing. Consequently, we have included new content and Autodesk ReCap software in 2018 to further process the point cloud data from the laser scanning for 3D modelling. .

Offering experiential learning opportunities have been shown in the research to have enhanced student recruitment, retention and completion rates as well as an increase in interest in post-graduate studies (Bartle, 2015). Our experiences bear testimony to these findings. Since the inception of the practice course in 2012, the workshop has been in high demand, and had to be repeated in the fourth-year practice course due to student demand, and also had to be offered at both the Toowoomba and Springfield campuses to meet demand. Our graduates equipped with TLS knowledge and skills play an important role in promoting the development and applications of the TLS in surveying and spatial science profession as well as in the engineering disciplines.

The theoretical knowledge of TLS was enhanced and linked to students' previous experiences in the study of Advanced Surveying course, which systematically introduces the principle of TLS in more details. It also includes error analysis, project planning, field work procedure, data processing and applications of TLS. On successful completion of the TLS workshop and the Advanced Surveying course, students are equipped with the knowledge and skills to undertake undergraduate research projects in TLS and applications

The student surveys revealed that more than half of the students expressed an interests in conducting TLS-related projects for their final year undergraduate research (or capstone) projects. Final year research project work undertaken by students studying for honours degrees is a critical part of practice. The project is intended to contextualise the final phase of academic study and integrate and augment the students' knowledge by means of its application to a real problem at the appropriate professional level, in line with the fourth stage of the experiential cycle of learning. The development and inclusion of the TLS workshop and the Advanced Surveying course led to an increase in the number of students who have undertaken TLS-related projects since 2012, a finding in line with experiential learning research that experiential learning appears to have a motivating impact on students (Bartle, 2015). The TLS research projects cover a wide range of application areas, including building information modelling (BIM), mining surveying, 3D cadastral surveying, biomass and carbon estimation, mobile laser scanning, and some advanced research projects. The next section presents some examples of TLS projects supervised by the authors. It details student work in TLS to provide a broader understanding of the applications available to other professions.

Undergraduate research projects of TLS

The undergraduate research project provides the students the semi-structured learning opportunities that are typical in an experiential learning paradigm where the role of the teacher is to facilitate rather than direct the student's progress (Kolb & Kolb, 2009). In the context of the final year research project, the student is expected to take initiative by suggesting a research topic, searching for the appropriate literature, proposing an appropriate methodology, analysing data and crafting a dissertation. In this process they make the decisions and bear the responsibility for those decisions. It also enables students to apply their knowledge to real-life problems (Bartle, 2015; Illeris, 2007).

TLS for BIM

BIM is a 3D model-based process used in Architecture, Engineering and Construction (AEC), providing an efficient means of digital representation of detailed information on building components, geometry, spatial relationships, and semantic properties in three-dimension (3D) space (Kreider & Messner, 2013; Succar et al., 2012). BIM helps understand spatial and semantic properties of buildings and provides the basis for a variety of functional analyses and applications such as facility management and maintenance, heritage (archaeology and architecture) protection, building deformation monitoring, town planning and decision support for all stages of the project's life cycle. The key aspect of BIM is to use an efficient way to obtain 3D building data for detailed description of building structure (Zhang & Liu, 2019). Recently, it has also been realised that the TLS will have a great potential for efficient 3D data collection in support of BIM applications (Shanbari et al., 2016; Shelbourn et al., 2017; Stančić et al., 2014). Figure 2 show a student project of using Leica ScanStation 2 terrestrial laser scanner for BIM and visualisation in Google Earth.

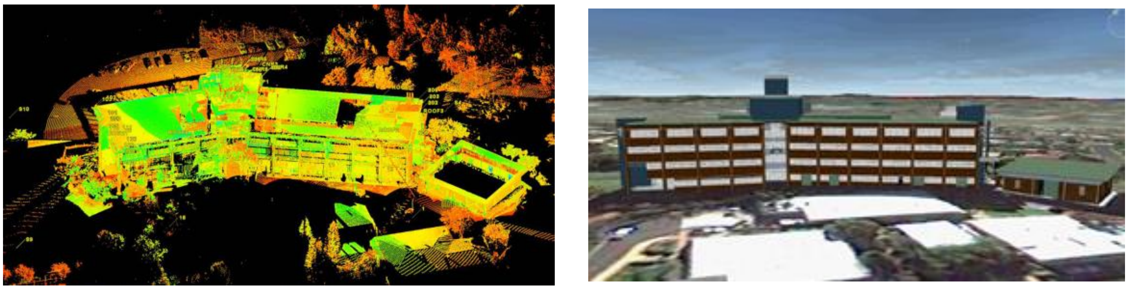

Figure 2: Laser scanning for BIM and visualisation in Google Earth

TLS for mine surveying

The Mining industry is one of the major employment sectors for surveying graduates. Mine surveyors play a key role in maintaining an accurate plan of the mine site, updating maps of the surface structure, and surveying the underground mine operation. TLS can be used to generate 3D models for accurate stockpile volumes calculation and provide an integrated solution in support of mine modelling tasks. The final year projects offer good opportunities for students to combine their knowledge and skills of TLS to a real project in mine industry. The example of the application of TLS in an open cut mining environment is shown in Figure 3.

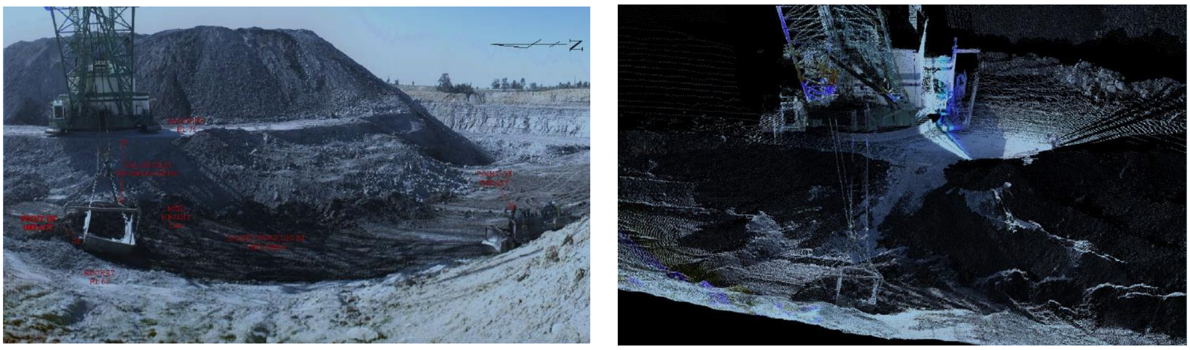

Figure 3: Application of TLS in an open cut mining environment

TLS for forest structure modelling and biophysical feature extraction

Forests play an important role in the global carbon balance and make a significant contribution to mitigation of climate change. In recent years, policies have been developed to increase the carbon sequestration role of forests in Australia and other countries. Accurate description of forest structure is essential for forest biomass and carbon estimation. Remotely sensed data have been widely explored for forest applications. However, passive remote sensing techniques are limited in their ability to capture forest structure complexity, particularly in uneven-aged, mixed species forests with multiple canopy layers. It has been shown that active remote sensing techniques via laser scanning with capability of canopy penetration yields such high-density point clouds that detailed description of the forest canopy structure in three dimensions can be obtained. The TLS offers a great potential to accurate forest structure modelling, biophysical feature extraction, and biomass and carbon estimation. Figure 4 shows a project example of using the TLS for forest structure modelling and biophysical feature extraction.

Figure 4: Application of TLS for biophysical feature extraction

TLS for 3D cadastral application

The following example demonstrates an application of TLS-created BIM for visualisation of 3D cadastre and attached complex rights. Figure 5 shows laser scanning point cloud of an apartment basement car park (left) and the model of the basement (right). Once the car park model was produced, the cadastral information of the basement car park was incorporated into the model. As a result, cadastral boundaries which are intangible in such a site as the basement car park can be directly and physically measured from the model.

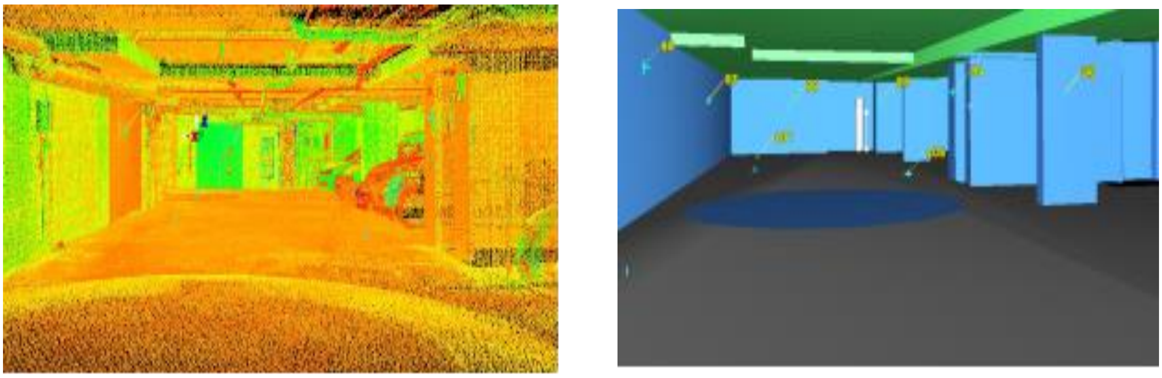

Figure 5: TLS for cadastral application

Accuracy assessment of TLS in a rail environment

The TLS has been demonstrated as an efficient means for high-density spatial data collection. However, different application areas have different requirements for accuracy, field procedure, and data processing standard. Furthermore, the TLs is still a relative new technology. It is necessary to test and verify the accuracy and efficiency in different application environments. The following is an example of student project attempting to test an application of TLS in rail environment and demonstrate that the TLS can be used for survey work within the rail corridor.

Figure 6: TLS in a rail environment

Mobile laser scanning

Mobile TLS (or referred to as MLS) is an integration of TLS, cameras, a GNSS receiver, inertial measurement unit (IMU), distance measurement indicator (DMI, a vehicle wheel revolution counter), and other devices. MLS has been used as an efficient survey method in many engineering and science applications. It is emerging recently as an advanced choice for mapping in transportation (Johnson et al., 2016). A recent student project tested the application of the MTL in transportation infrastructure mapping and road surface measurement.

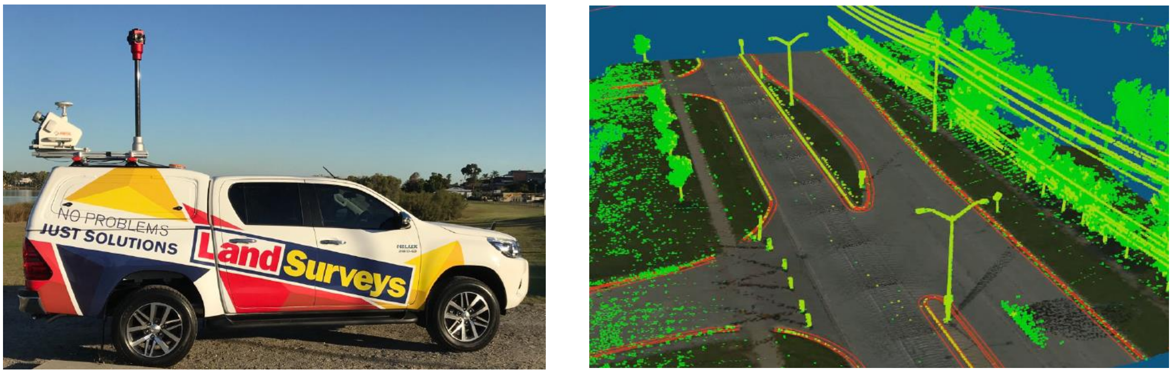

Figure 7: Mobile laser scanning

Conclusions

The emergence of new technologies has a significant impact on the surveying profession. TLS has emerged as an effective and efficient means of high-density and high-accuracy spatial data collection. Universities are required to prepare students to be global citizens and to be able to apply their knowledge and skills to real-life problems. The Institute of the Future (2011) has identified the required skills that students will have. These include novel and adaptive thinking, trans-disciplinarity, the ability to navigate shifting landscapes. Our application of experiential learning in our surveying curriculum, and specifically in our courses teaching TLS lends itself to the development of these higher-level graduate attributes. In recognition of the need for more accurate and efficient spatial data collection, as well as the need to enhance students' higher order graduate capabilities, experiential learning opportunities have been implemented for surveying students in the School of Civil Engineering and Surveying at USQ over the last decade. These strategies include the development and implementation of an industry-supported TLS workshop, a scaffolded Advanced Surveying course, and the promotion of TLS and its real-life applications in undergraduate research projects.

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