DESIGN AND IMPLEMENTATION OF THE INTEGRATED PRACTICUM OF GEOMATICS ACCORDING TO ENGINEERING EDUCATION ACCREDITATION

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KEY WORDS: Engineering Education Accreditation, Washington Accord, Practicum, Geomatics Engineering, Integrated practicum of Geomatics, Photogrammetry

ABSTRACT:

Engineering education accreditation is a new engineering education model promoted by the Ministry of Education in China, which aims to cultivate the ability of students to solve complex engineering problems. A course named "integrated practicum of Geomatics" (IPG) was innovatively designed for the undergraduate specialty of Geomatics. This course involves in the current advanced technologies to lay a solid foundation for students to engage in Geomatics through aerial photography technology design, unmanned aerial vehicle photography, control point selection, GNSS-RTK control point survey, photo interpretation and sketch, 3D (DEM, DOM, and DLG) product production, inputting 3D products into the Geodatabase, and GIS application software development. This paper expounds on the objectives, contents, evaluation methods, and continuous improvement of IPG.

1. INTRODUCTION

The Washington Accord (WA) is an international agreement among bodies that are responsible for accrediting engineering degree programs (International Engineering Alliance, 2014). Among the international agreements that govern the mutual recognition of academic or professional qualifications of engineering education all over the world, WA is the earliest signed agreement with the largest number of contracting parties and is the most well-known international certification agreement of engineering education. It outlines the mutual recognition of accredited engineering degree programs among the participating bodies and establishes a benchmark for professional engineering education across these bodies.

The WA currently has 20 signatories. On June 2, 2016, China officially became the 18th signatory, which means that the quality of undergraduate engineering education in China has reached the international certification standards and that the undergraduate degrees awarded by engineering educational institutions in the country have satisfied the international mutual recognition quality standards.

Educational and professional accords for the mutual recognition of qualifications and registration have issued statements on the ideal graduate attributes and professional competence profiles. In China, engineering qualifications are defined by the China Engineering Education Accreditation Association, which has issued 11 professional competence profiles for engineering students in higher education in recent years (International Engineering Alliance, 2021). These profiles are designed to evaluate the comprehensive abilities of these students, including their communication, cooperation, professional knowledge and skills, lifelong learning ability, world outlook, and to set clear directions and requirements for teachers and educational institutions in designing their courses. Corresponding to these professional competence profiles are 12 graduate attributes that measure the abilities of students upon their graduation. These attributes also provide a point of reference for educational bodies to describe the outcomes of substantially equivalent qualifications (China Engineering Education Accreditation Association, 2022).

Geomatics is a sub-discipline of engineering. Talents trained in this discipline are expected to have solid basic theoretical knowledge and practical ability. Canada is one of the leading countries in the world of Geomatics engineering education. In Canada, there are four engineering schools provide four-year undergraduate geomatics engineering program (Pagiatakis et.al.,2009). These programs all have developed modern curriculum, and have received professional accreditation. The Geomatics engineering program in university of Calgary highlights the collaborative team work on projects and provide full-time paid engineering work experience through a 12–16-month placement (https://www.ucalgary.ca/). For a long time, Geomatics education in China has attached importance to theory, knowledge and results while ignoring practice, ability, and processes. With the growing importance of practical teaching, the establishment of a scientific practical teaching system becomes critical in undergraduate engineering education. Cultivating the ability of students to solve complex engineering problems is not only a standard of the WA but also a social demand for engineering talents.

The Geomatics engineering program of the Beijing University of Civil Engineering and Architecture was awarded the certification of international engineering education specialty in 2015. This program is being taught in accordance with the certification standards for engineering education. "Integrated practicum of Geomatics" (IPG) is a comprehensive practical teaching course that lasts for six weeks during the senior year. IPG focuses on the comprehensive application of theories on surveying and mapping, photogrammetry, and GIS that students have been learning for four years in order for them to fully grasp the knowledge they have learned, exercise their actual production ability, deeply grasp the basic engineering concepts and principles, and cultivate their ability to analyze and solve problems and cooperate with teams. At present, IPG is the most comprehensive course being offered at the School of Geomatics and Urban Spatial Information of the Beijing University of Civil Engineering and Architecture and is being taught by the greatest number of teachers in the school.

2. IPG COURSE DESIGN

2.1 Course objectives

Establishing implementable and evaluable curriculum objectives is the key to curriculum construction, and the achievement of teaching objectives determines the degree of achieving the ideal graduate attributes. IPG plays an important supporting role in the curriculum system. Among the 12 graduation attributes, "Design/development solutions" and "Research" are supported by 2 performance indicators, whereas "Engineering and society," "Individual and team," and "Communication" are each supported by 1 indicator. These performance indicators serve as bases for formulating the IPG curriculum objectives. Table 1 lists the performance indicators and curriculum objectives supported by IPG.

Graduate attributes		**Curriculum objectives**
3. Design/development of solutions:	3.1 Be able to design technical solutions according to the needs of users in surveying and mapping, remote sensing, and geographic information engineering and understand various factors affecting the design objectives and technical solutions	Course objective 1: Be able to design the technical scheme of data acquisition for UAV flight according to the requirements of 1:500 scale mapping products (mainly including DEM[1], DOM[2], and DLG[3]) to meet the technical requirements of mapping. Understand the influence of flight height, lens, aerial photography season, and time of UAV flight on flight quality.
	3.2 Be able to develop production processes and systems that meet the requirements of geomatics data acquisition, processing, and application	Course objective 2: Be able to develop a GIS application software that can meet the requirements of managing stored DEM, DOM, and DLG data.
4. Investigation	4.3 Be able to use scientific methods to implement Geomatic data acquisition, analysis, and processing	Course objective 3: Be able to correctly implement UAV image acquisition, field acquisition of ground control points, photo interpretation and sketch, use digital photogrammetric software to realize DEM, DOM, and DLG data production, input DEM，DOM, and DLG data into the geodatabase, and other work according to the requirements of the specification.
	4.4 Be able to conduct information synthesis and evaluation on the experimental results and obtain reasonable and effective conclusions	Course objective 4: Be able to evaluate the flight and photography quality of the images collected by UAVs, judge whether the coordinates of the control points collected by GNSS-RTK meet the accuracy requirements, and reach reasonable and effective conclusions.
6. The Engineer and the World	6.2 Be able to evaluate the importance of Geomatics surveying and mapping results to society, health, law, culture, national security, and territorial integrity as well as the impact of these constraints on the implementation of the project and understand the responsibilities that should be borne by Geomatics engineering practice	Course objective 5: Be able to evaluate the important influence of UAV flight and mapping results on society, health, law and culture, national security, and territorial integrity and the impact of these constraints on project implementation and understand the responsibilities of geomatics engineering practice.
9. Individual and Collaborative Teamwork	9.3 Be able to organize, coordinate, and command the team to carry out work	Course objective 6: Be able to organize, coordinate, and command groups of students to carry out UAV flight, photo control survey, field mapping, and other work together.
10. Communication	10.1 Be able to effectively communicate and exchange with peers and the public about complex geomatics engineering issues during the preparation of design documents, technical reports, and presentations	Course objective 7: Be able to effectively communicate with team members, instructors, and flight management departments during the preparation of aerial photography flight technical design and presentation.

Table 1 Relationship between curriculum objectives and graduate attributes (1 Digital Elevation Model; 2 Digital Ortho Map; 3 Digital Line Graphic)

2.2 Course implementation conditions

2.2.1 Site of Practicum

The practice site includes the outdoor UAV experiment field and the indoor data processing computer lab.

Given that the university is located in Beijing where flying UAVs are prohibited in most areas, the UAV experiment base in Zhouzhou, Hebei Province was selected as the field practice site. This open site has a superior clearance environment and legal airspace. To meet the test load, two runways of different sizes (400× 12 m, 200 × 6 m) are built. The selected area is 2.25 square kilometers, which is divided into 36 pieces at the scale of 1:500. The area is 1500 meters long from east to west and from south to north. The survey terrain is flat and has no high-rise buildings, making it suitable for aerial photography practice of UAV. There are three villages in the survey area, namely, Houying Village, Liuheying Village, and Chu Village. The land cover includes houses, cultivated land, roads, vegetation, pipelines, ditches, factories, and schools.

The Beijing University of Civil Engineering and Architecture has a student computer lab with 120 computers, which meets the requirement of one computer per person.

The practicum is conducted in groups. Each team is required to complete the production task of two 1:500 scale 3D products (mainly including DEM, DOM, and DLG). The red box in Figure 1 represents the coverage of each 1:500 map, the first digit of the two-digit number represents the group number, and the second digit represents the intra-group map number.

Figure 1. Distribution of the survey area of the site

2.2.2 Main instruments and equipment required for practicum

The field equipment includes a GNSS-RTK receiver, DJ PHANTOM 4 RTK UAV, image control point template, spray paint, sign board, and photo printer. Meanwhile, the lab software includes the GeoLord/Photoscan analytic aerial triangulation software, MapMatrix digital photogrammetric system, and ArcGIS/SuperMap desktop software and development components.

3 CONTENT AND REQUIREMENTS

The practicum begins with the field part. After entering the site, students need to investigate the survey area, collect previous data (mainly including topographic maps and coordinates of existing control points), and learn how to control the UAV for data collection. These works are necessary for the preparation of the aerial photography design book. IPG can be divided into field work and computer lab work according to the process. The contents and requirements are as follows.

3.1 UAV trajectory design and image acquisition

The main course contents include the designing of aerial photography technical book, the implementation of UAV aerial photography, and the evaluation of the flight quality of the photos. This part of the course is conducted in the UAV experiment field for 3 days and mainly covers the course objectives 1, 3, 4, 5, 6, and 7 (in Table 1).

To adapt to the needs of Geomatic production work after employment, students are made aware of some relevant production specifications during their internship. They are required to familiarize with the low altitude digital aerial photography specification CHZ 3005-2010 (National Bureau of Surveying and mapping, 2010) and prepare an aerial photography technical design book in accordance with this specification from several aspects, such as the division of the shooting area, the direction of route laying, the time of photography, the coverage of the aerial photography range, the degree of image overlap, and the selection of ground resolution. They are required to master the aerial photography operation of consumer UAVs and perform aerial photography tasks by communicating with air traffic controllers, local residents, instructors, local surveying and mapping companies, team members, and team leaders. They need to learn how to carry out flight quality checks and submit reports on image overlap, image inclination, image rotation angle, and course curvature.

This part of the practicum requires the submission of group results, including a technical design of aerial photography, UAV aerial photography, UAV RTK field data, aerial photo index map, and flight quality inspection report.

(a) (b)

Figure 2. (a) UAV operation training (b) route image mosaic

3.2 Image control points and check points measurement

The photo control points are selected according to the position and quantity mentioned in the specification. GNSS-RTK is then used to acquire the coordinates of the control points and check points. Afterward, these points are evaluated for their accuracy. This part of practicum is conducted in the UAV experiment field for 2 days and mainly supports the course objectives 3, 4, and 6 (in Table 1).

The students are required to master the requirements for the placement of image control points in accordance with the specification for fieldwork of low-altitude digital aerial photogrammetry CH / Z 3004-2010 (National Bureau of Surveying and mapping, 2010), master the method of measuring and inspection the coordinates of image control points using GNSS-RTK, and analyze the accuracy of the collected control point coordinates. Each image control point needs to have a control point picture for subsequent processing. In this part, each group needs to submit the control point and check point results, an accuracy analysis report, and a control point picture.

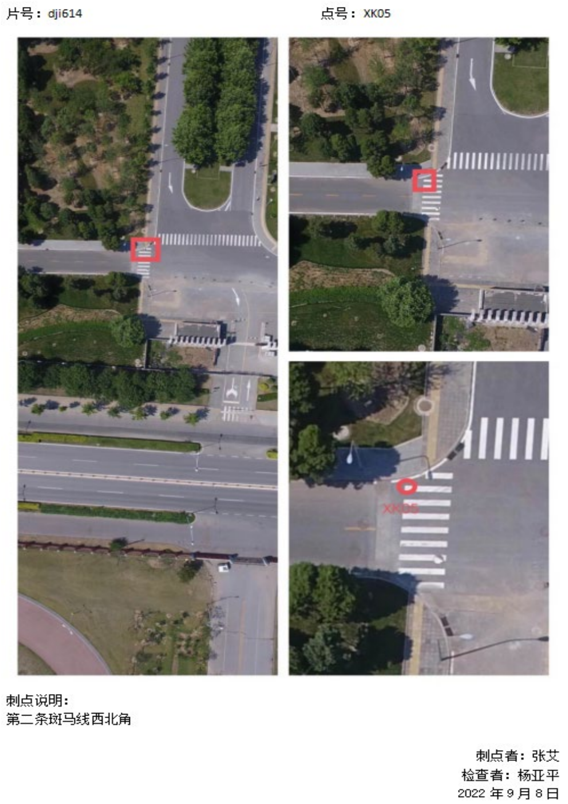


Figure 3. control picture example

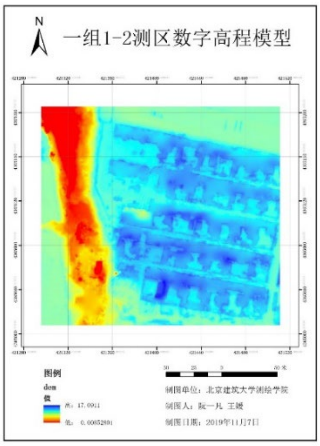
3.3 Photo interpretation and sketch

The main contents of this part include photo interpretation, field sketching, and production of a sketching picture, which will be used in subsequent works. This part of practice is conducted in the UAV experiment field for 2 days and mainly supports the course objectives 3, 5, and 6 (in Table 1).
The students are required to coordinate and develop a mapping plan in groups with reference to the field specifications for low-altitude digital aerial photogrammetry, master the method of sketching each element of the topographic map, and decorate the results according to the specifications.
By the end of this part, each group needs to submit sketched pictures

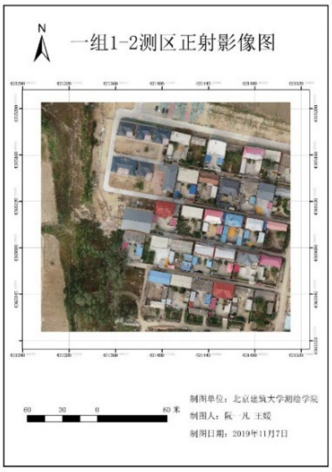
Figure 4. scene of photo interpretation and sketch

3.4 DEM, DOM, and DLG production

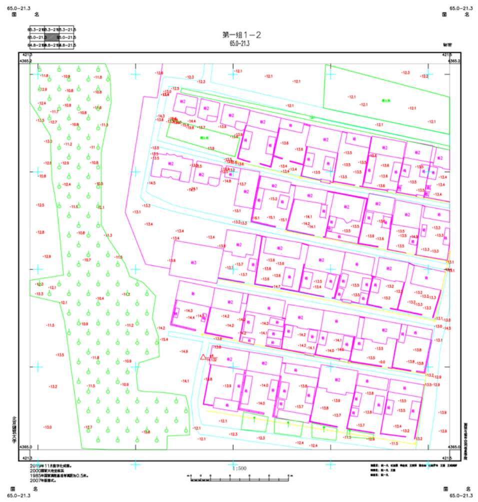
The main contents of this part include using analytical aerial triangulation software to increase the density of control points to meet the requirements of subsequent 3D (DEM, DOM, and DLG) production. The students are required to use Geolord or Photoscan to analyze aerial triangulation in accordance with the specification GB / T 23236-2009 (National Bureau of Surveying and mapping. 2009) for aerial triangulation of digital aerial photogrammetry to determine the exterior orientation elements of all photos in the area.
Then the following work include producing DEM, carry out orientation, quality inspection, and correction based on a 3D model; Producing DOM via the digital differential correction method and output it according to the map frame; DLG data acquisition and editing, and splicing and cutting of DEM, DOM, and DLG to generate standard sheet and scale products. As a team, they should be able to use MapMatrix to complete the DEM, DOM, and DLG acquisition of two 1:500 topographic maps and to evaluate whether the collected results meet the requirements of the specification CH / Z 3003-2010 (National Bureau of Surveying and mapping, 2010). DEM, DOM, and DLG products can be generated according to the standard map sheets. This part of the practicum is scheduled to be completed in the indoor computer lab for 10 days because the editing of DLG needs to be completed manually and the workload is large. This part mainly supports the course objective 3 (in Table 1).
By the end of this part, each group is required to submit two 1:500 scale DEM, DOM, and DLG.



(a)



(b)



(c)

Figure 5. examples of student' submission(a) DEM. (b) DOM and (c) DLG

3.5 Input the 3D products into the Geodatabase

In this part, the students are expected to use ArcGIS/SuperMap and other desktop software as well as Oracle/SQL Server and other databases to edit and store the spatial data of DEM, DOM, and DLG. The contents of DLG are inputted into corresponding layers according to the layering requirements of topographic map elements. This part is conducted in the indoor computer lab for 3 days and mainly supports the course objectives 3, 6, and 7 (in Table 1).

The students are required to create corresponding datasets from DEM and DOM and store them. If these datasets need to be stored in standard map frame pieces, then the students should ensure a seamless splicing between pieces. For DLG, the students need to create a Geodatabase and the corresponding datasets for different layers according to the features of the topographic map. Afterward, they need to edit the features represented by points, lines, and polygons on the DLG, add attributes, check the topological relationship after editing, make the necessary modifications, and complete the establishment of a spatial database.

In this part, each group is expected to submit their database results, which should be exported as a personal database file (*.mdb).

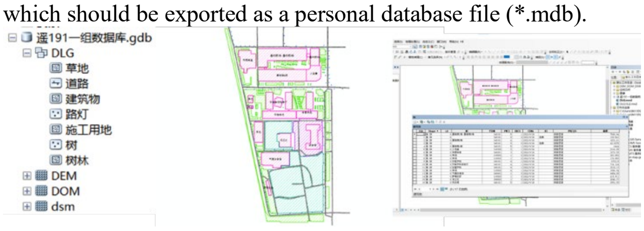


Figure 7. examples of Geodatabase created

3.6 GIS application software development

This part of the practicum aims to design and develop the application GIS software using several programming languages (such as C #) and the GIS secondary development components for the stored DEM, DOM, and DLG data. This part is carried out in the indoor computer lab for 5 days and mainly supports the course objectives 2, 6, and 7 (in Table 1).

The students are required to develop the application GIS software to be able to read and display the DEM, DOM, and DLG, superpose the DEM and DOM to form a 3D terrain display, generate spatial queries (attribute and geometric queries) and statistics, conduct spatial analysis (buffer, overlay, and shortest path analyses), produce a thematic map, classify the grid database (DOM), conduct a slope analysis of DEM, and realize the network release of DEM, DOM, and DLG data (this work is optional).

Each group is expected to submit its developed software and source code.

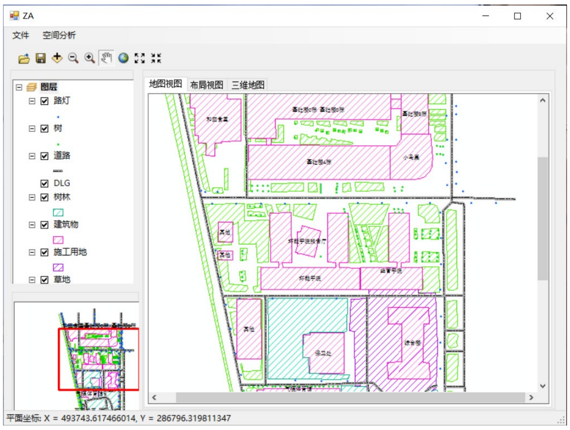


Figure 8. examples of GIS application software development

4 ASSESSMENT AND PERFORMANCE EVALUATION

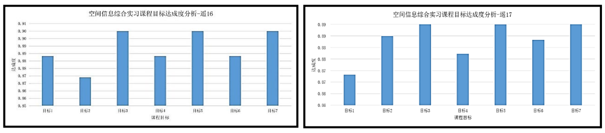
The evaluation of the achievement of curriculum objectives serves as the basis of the continuous improvement of curriculum according to the requirements of engineering accreditation. The score of each student is computed in consideration of the following aspects: ① the aerial photography technical design submitted by the group, accounting for 10% of the total score (supporting course objectives 1 and 7); ② the quality of the control and check points measurement, photo interpretation, and sketch and 3D product, accounting for 10% (supporting course objective 3), ③ the quality of the group UAV flight image and flight quality evaluation report, accounting for 10% (supporting course objective 4), ④ the results of inputting 3D products into the Geodatabase, GIS design, and software development quality, accounting for 30% (supporting course objective 2), ⑤ the personal presentation, accounting for 10% (supporting course objective 5), ⑥ the personal comprehensive performance (attendance rate, practice attitude, and instrument care), accounting for 10% (supporting course objective 6), and ⑦ the quality of practicum diary and practicum summary, accounting for 20% (supporting course objective 6).

The instructors set up a scoring sheet to rate the submissions of each group, list the individual and personal statements according to the provisions of the course outline, and calculate the scores of each student. The above course assessment methods comprehensively evaluate the ability of students to achieve each course goal, and the final results accurately reflect the comprehensive performance of each student in the practicum process.

5 COURSE IMPLEMENTATION AND CONTINUOUS IMPROVEMENT

The complex process and numerous contents of IPG will leave most students feel frustrated. Many students harbor negative emotions toward the course, such as laziness and fear of facing difficulties in their practical courses. However, this practicum is implemented by means of phased training and phased submission of results, thereby ensuring that students can easily obtain experimental results, have a certain sense of achievement, and

maintain their interest in follow-up practice.
In the past, the practical teaching courses of undergraduate majors in Geomatics all adopted a single type of practice, such as GPS control survey, production of 4D products of a photogrammetric workstation, and GIS software development. The decentralized practical teaching method depends on the content of each section and cannot realize the overall concept of Geomatics. By contrast, the high-intensity practice mode of IPG, which lasts for six consecutive weeks, can improve the students' understanding of surveying and mapping, photogrammetry, and geographic information practice as a whole.
The establishment of a continuous improvement mechanism is critical to improving the quality of curriculum teaching. After each round of teaching, the achievement of the course objectives needs to be analyzed and summarized from both qualitative and quantitative aspects. For those course objectives that have not been achieved or have a low degree of achievement, it is necessary to find out the reasons behind the failure, propose improvement measures, and make continuous improvements in the next round of teaching. Four sessions of IPG have been carried out thus far. The 2016 batch reported lower evaluation results for course objectives 2 and 4 (Shown in Figure.9). The teaching team then analyzed the reasons behind these results and then adjusted the difficulty, workload, and length of software development. Moreover, detailed guidance books have been prepared and counseling programs have been arranged to help students address challenging accuracy evaluation problems. These changes resulted in a significant improvement in the achievement of course objectives in the following batch.



(a) (b)

Figure 9. examples of continuous improvement. (a) achievement of Grade 2016 level course objectives. (b) achievement of Grade 2017 level course objectives.

6 CONCLUSION

IPG follows the rules of engineering education accreditation, integrates the advanced hardware and software tools of the current Geomatics industry, and is consistent with the development of industrial technology, thereby addressing the problem where traditional teaching contents lag behind modern technologies. The innovation lies in that IPG integrate data acquisition, data processing, and application software development all in one practicum, enable students to fully grasp the complete process of Geomatics industry through the six weeks internships.
IPG provides a foundation for students to solve complex engineering problems and enter working positions. On the one hand, through IPG, students are trained in the production and technical ability of Geomatics, and the professional knowledge they learn throughout their four years of university is consolidated through practice. On the other hand, IPG trains the ability of students to work as a team and develops their communication skills.
Evaluating the curriculum goals of IPG serves as the foundation of its continuous improvement. This program will be improved gradually based on the concept of engineering education accreditation.

Student ID	Name	Aerial photography technical design (course objectives 1 and 7) 10%	Control and check points measurement, photo interpretation, and sketch and 3D product quality score (course objective 3) 10%	UAV flight image and flight quality evaluation report (course objective 4) 10%	Inputting the 3D products into the Geodatabase, GIS design, and software development quality (course objective 2) 30%	Personal presentation (course objective 5) 10%	Personal comprehensive performance (course objective 6) 10%	Quality of practice diary and practice summary (course objective 6) 20%
		Group achievements account for 30%			GIS part 30%	Achievements completed by individuals account for 40%		

Table 2 CPSIAP scoring sheet

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