

# Enhancing Geomatics Engineering Education with Software Engineering Attributes

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## SUMMARY

Today, it is the widespread digital transformation that is having a profound impact on all aspects of geomatics engineering technologies and is putting unprecedented pressure for radical changes on university curricula. With billions of devices connected to the IoT and the earth observation systems mounted on satellites, aircrafts and UAVs, executives and decision-makers have access to voluminous geospatial data. A growing challenge for geomatics engineers is to build "location intelligence" by processing, analyzing, and visualizing massive volumes of geospatial data to empower holistic planning, prediction and problem solving. More than ever, geospatial industry is seeking for geomatics professionals with strong software engineering skills. To address the high industry demand, geomatics engineering curricula should be enhanced with software engineering attributes.

At the University of Calgary, Canada, we recently introduced a Software Engineering minor program to bring a distinct understanding of software engineering knowledge (and associated skillset) to students in the Geomatics Engineering major program (BSc). The scope of this paper is to provide an overview of the new minor program, its structure, and some initial measures of its impact. By embedding solid software engineering attributes and learning outcomes in geomatics engineering curricula, there is strong potential to: (i) facilitate geomatics engineering graduates to pursue more diverse career pathways; (ii) increase awareness and interest in the natural intersections between geomatics engineering and software engineering among high school graduates and raise the enrollment in geomatics engineering programs; and (iii) improve diversity and inclusivity – especially in terms of gender balance in geomatics engineering programs.

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## 1. INTRODUCTION

Founded in 1979 to support the mapping and land surveying needs in Western Canada, the Department of Geomatics Engineering (former Department of Surveying Engineering) at the University of Calgary has been a renowned international leader for innovation in education and research over four decades of rapid technological advancements. The department has kept pace with its outstanding achievements during a multi-stage transformation of the geomatics industry that disrupted and shifted the focus from the traditional surveying and mapping methods of the 1970's to the technological advancements in positioning and navigation systems, satellite and earth observation systems, web mapping systems, geospatial data science, and geospatial intelligence. Today, the department is the largest of its kind in Canada, and top-ranked globally.

The department offers an undergraduate major BSc degree in Geomatics Engineering with 5 minors (Software, Aerospace, Digital, Biomedical, Energy and Environment) and one concentration (Cadastral Surveying). The BSc in Geomatics Engineering is a four-year degree program, fully accredited by both the Canadian Engineering Accreditation Board (CEAB) and Canadian Board of Examiners for Professional Surveyors (CBEPS). The department offers three graduate programs, that include a course-based Master's degree in Geomatics Engineering (MEng), and two research-based degrees, the Master of Science (MSc) and the Doctor of Philosophy (PhD) in Geomatics Engineering. The graduate degree programs specialize in four research priorities: geodesy, remote sensing and earth observation; digital imaging systems; positioning, navigation and wireless location; and GIScience and land tenure.

Over the last few decades, the rapid evolution of geomatics engineering as a discipline has created high industry demand for geomatics engineers with a strong background in software engineering. At the same time, the undergraduate software engineering program (offered by the Department of Electrical and Software Engineering) at the University of Calgary has recently become one of the largest major programs in the Schulich School of Engineering. Two years ago, the Department of Geomatics Engineering and the Department of Electrical and Software Engineering have undergone significant discussion, consultation, and collaboration that (over time) evolved into the minor program in Software Engineering, an optional program to all students in the Geomatics Engineering major program (Bsc), which is presented in this article.

The software engineering minor program, the first of its kind offered within a geomatics engineering department in Canada, addresses an increasing industry demand and increases awareness and interest in the natural intersections between geomatics engineering and software engineering. It also opens new pathways in research and in the profession for future graduates of the program.

## **2. MINOR PROGRAM IN SOFTWARE ENGINEERING**

### **2.1 Program description**

In the Schulich School of Engineering, minor programs have been developed to offer a distinct branch of knowledge (and associated skillset) that supplements the school's major undergraduate programs. A minor program requires a minimum of 10 term long courses distributed over and normally completed within four years of study (or three years if the common 1<sup>st</sup> year for all engineering students is excluded) required for a bachelor's degree in engineering. Minor programs are not typically associated with the student's major field of study. The minor in software engineering aligns with this approach and seeks to bring a distinct understanding of software engineering knowledge (and associated skillset) to students in the geomatics engineering major.

The minor program in software engineering has been housed within the Department of Geomatics Engineering and has only been offered to undergraduate engineering students who are successfully placed in the geomatics engineering major. The courses in the minor program have been specifically selected to complement and enhance the major's curriculum. The minor program itself is optional and not required for graduation.

Students apply for admission to the geomatics engineering major and the minor in software engineering during their first year in the Schulich School of Engineering, which is common for all engineering students. Admission to both the major and the minor requires students to successfully complete the first year of the BSc in engineering. There are no additional admissions requirements that are specific to the minor.

In the minor program, geomatics engineering students take both core and technical elective courses in software engineering. These courses have been offered by both the Department of Electrical and Software Engineering and Department of Geomatics Engineering. During their final year of study, students take a yearlong capstone design course, where they work with their peers in the minor to complete industry-relevant design projects in software engineering with specific applications in geomatics engineering.

The intended purpose of the minor in software engineering is to enhance the traditional geomatics engineering curriculum with an understanding of the fundamentals of software engineering, emerging software engineering technologies, and software engineering design methods. This minor would allow students to become leaders in emerging areas of the geomatics engineering industry. As geomatics engineering (and related industries) are poised

to become a significant economic engine both provincially and nationally, a strong background in software engineering would allow students to pursue diverse career pathways that are less accessible to graduates of a traditional geomatics engineering program.

## 2.2 Curriculum design

The curriculum for the minor in software engineering was developed using several different approaches. Faculty members in the Department of Geomatics Engineering collaborated with their peers in the Department of Electrical and Software Engineering to develop a solid understanding of software engineering as a discipline and to identify appropriate fundamental courses for inclusion in the proposed minor.

At the same time, faculty members in the Department of Geomatics Engineering have consulted with their peers in academia and industry across Canada to determine the most in-demand skills and curriculum content for both employers and students. The Department of Geomatics Engineering has an industry advisory committee (GEAC – Geomatics Engineering Advisory Committee) that consists of both Canadian and international industry leaders in geomatics and software engineering. The industry demand for geomatics engineers with a background in software engineering has long been discussed within the GEAC, and the proposed minor has the strong support of all committee members.

As already mentioned, minor programs at the University of Calgary generally require 10 term long courses, which are distributed in three years of study (2<sup>nd</sup> through 4<sup>th</sup>). The minor program in software engineering includes the following courses:

### Mandatory courses:

- ENSF 300 - Software Engineering Practices for Data Management (2<sup>nd</sup> year, Fall)
- ENGO 333 - Computing for Geomatics Engineers (2<sup>nd</sup> year, Fall)
- ENSF 409 - Principles of Software Development (2<sup>nd</sup> year, Winter)
- ENSF 480 - Principles of Software Design (3<sup>rd</sup> year, Fall)
- ENSF 444 - Machine Learning Systems (3<sup>rd</sup> year, Winter)
- ENGO 537 - Spatial Databases and Data Mining (4<sup>th</sup> year, Winter)
- ENGO 551 - Advanced Geospatial Topics (Geospatial Web, Geosensors, IoT) (4<sup>th</sup> year, Winter)
- ENGO 500 - Capstone Project (4<sup>th</sup> year, Fall & Winter)

### Elective courses (students in the minor choose 3 courses from this list):

- ENSF 554 - Data Science for Software Engineers
- ENSF 545 - Introduction to Virtual Reality
- SENG 513 - Web-based Systems
- ENEL 573 - Computer Networks
- ENCM 509 - Fundamentals of Biometric Systems Design
- ENCM 517 - Computer Arithmetic and Computational Complexity
- ENEL 563 - Biomedical Signal Analysis

- ENGO 531 - Advanced Photogrammetric and Ranging Techniques
- ENGO 545 - Hydrographic Surveying
- ENGO 559 - Digital Imaging and Applications
- ENGO 563 - Data Analysis in Engineering
- ENGO 585 - Wireless Location

### **2.3 Modes of Delivery**

The majority of courses in the minor have been delivered in a face-to-face classroom coupled with hands-on, experiential lab work designed to complement classroom learning. In addition to a strong theoretical background, this program is designed with numerous hands-on opportunities for students that help them attain a wide array of technical skills in programming, intelligent data management and analytics, geospatial web development, system validation and testing.

As the program evolves, it is in the plans to explore opportunities to move a portion of the curriculum to a blended model in order to further increase the number of experiential learning opportunities available to students (e.g., simultaneous coursework and industry exposure as part of a co-op term or internship). Additionally, industry certificates (e.g., the Microsoft Certificate in Machine Learning, Esri Certificate in Geospatial Analytics) will soon become available to students through existing courses or summer seminars.

No formal work experience is required for the minor. However, the Schulich School of Engineering offers numerous internship opportunities to all undergraduate students. Geomatics engineering students enrolled in the minor in software engineering are welcome to apply to these opportunities and incorporate them into their program of study. Students have also been strongly encouraged to take advantage of the various experiential learning opportunities provided to them by the Schulich School of Engineering, including the development of formal and informal industry connections through open-house events and internships.

## **3. DISCUSSION**

The Department of Geomatics Engineering at the University of Calgary has been a world leader in education and research for over 4 decades. This accomplishment would not have been possible without continuous enhancement of the programs offered to our students, as our graduates have consistently been prepared to shape and contribute to the rapidly evolving discipline of geomatics engineering.

The introduction of the minor in software engineering is a response to emerging industry needs and aligns with the department's desire to innovate and support advances in student programming. The minor further enhances the breadth and quality of the current major program and supports our graduates in becoming world-class leaders in geomatics engineering.

Over the past few years, the BSc in software engineering has grown into one of the largest undergraduate major programs in the Schulich School of Engineering. At the same time, the number of faculty members in the Department of Electrical and Software Engineering has significantly increased to support this growth in demand and interest. This was an excellent timing to introduce the minor in software engineering for geomatics engineering students, given the growth of the Department of Electrical and Software Engineering and the popularity of the software engineering major to high school students.

We expect that the minor will strengthen the connection between the geomatics engineering major and the software engineering major and will increase awareness and interest in the natural intersections between geomatics engineering and software engineering among first-year engineering students. Our hope is that this connection will lead to an enrollment increase in the geomatics engineering major, while also improving diversity and inclusivity – especially in terms of gender balance in the existing program.

The software engineering minor was launched in September 2022, and the data collected so far are very promising. Specifically, the 2022-23 intake in Geomatics Engineering has shown a 65% increase compared to the previous academic year. From the students placed in the geomatics major program, 75% have also chosen to enrol in the software engineering minor. Those students experience has been monitored through regular surveys and has overall been very positive so far. The percentage of students identified as women in the 2022-23 intake is up to 31%, the highest percentage recorded in the program. The percentage of female students in the previous academic years was about 15% and the percentage for the current BSc cohort in the geomatics engineering major program is 20%. We strongly believe that these statistics will show further improvement in the next academic years, given the extensive outreach activities and industry support in the software engineering minor.

## REFERENCES

Calendar 2022-23, Geomatics Engineering with Software Engineering minor. URL: <https://www.ucalgary.ca/pubs/calendar/current/en-4-7.html> [Visited on 02/21/2023]

Geomatics Engineering, University of Calgary. URL: <https://schulich.ucalgary.ca/geomatics> [Visited on 02/21/2023]

Stefanakis, E., 2023. Why and how does geomatics engineering education need to change? *GIM International*, January 2023. URL: <https://www.gim-international.com/content/article/why-and-how-does-geomatics-engineering-education-need-to-change> [Visited on 02/21/2023]

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## **BIOGRAPHICAL NOTES**

Emmanuel Stefanakis, PhD, PEng, is a professor of geospatial data science and head of the Geomatics Engineering Department at the University of Calgary, Canada. He is a member of the Association of Professional Engineers and Geoscientists of Alberta, the Canadian Institute of Geomatics, and the Canadian Cartographic Association. His active service includes the Canadian Board of Examiners for Professional Surveyors, and the International Society for Photogrammetry and Remote Sensing.

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