EDU-UAV Photogrammetry Current Online Educational Landscape

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ABSTRACT

UAV photogrammetry plays an essential role in applications such as disaster management, food security, and mapping due to its adaptability, scalability, and accuracy in data collection. Consequently, the increasing popularity of the UAV photogrammetry domain has led to a growing demand for comprehensive education accessible through academic institutions. Meanwhile, the flexibility and freedom associated with online education have sparked significant demand for online learning programs. Different users actively seek online courses and materials to delve into the intricacies of UAV photogrammetry. However, the abundance of online resources in this area poses challenges in finding such reliable courses.
To address this challenge, the ITC team from the UAV centre and EOS Department at the University of Twente investigated the current online education courses related to UAV Photogrammetry offered globally. They compiled an inventory of these courses, categorizing them according to different educational levels- introductory, intermediate, and advanced—to align with the needs of key photogrammetry user categories. The project also investigated the currently available UAV datasets and software packages supporting technical training and professional applications. Further details are available on the project website.
Besides, the project gathers insights into gaps in UAV photogrammetry knowledge areas and UAV applications in geoscience by designing, distributing, and analysing a UAV Gap survey.

1. INTRODUCTION

This project, titled "EDU-UAV Photogrammetry Current Online Educational Landscape", funded by the ISPRS Capacity Building Initiative 2024, is carried out by the ITC faculty team at the UAV Center. The term "EDU-UAV" refers to the educational initiative focused on UAV (Unmanned Aerial Vehicle) photogrammetry, aiming to enhance the accessibility and quality of online education in this domain. UAV photogrammetry plays a significant role in many applications, such as environmental monitoring (Capolupo et al., 2015), disaster management (Kedys et al., 2024), (Giordan et al., 2018), food security (Muhammad Naveed et al., 2023), and utility management (Tilon et al., 2022). The advantages of using UAVs lie in their flexibility, scalability, adaptability, and reduced cost compared to traditional airborne or terrestrial instruments. UAVs have gained significant attention, and foresee a promising future for expanding their applications and enhancing technological capabilities.
The abundance of UAV photogrammetry online courses and materials across various domains and expertise levels has significantly enriched the learning landscape. However, this abundance of information and resources poses challenges for individuals and organisations in identifying reliable and accountable sources. As a result, there is a significant need for organised catalogue preparation to support the search for valuable and systematic information. Such an inventory serves as an accountable source, helping learners and educators efficiently filter massive online resources and access well-sourced information. Additionally, it could provide reliable insights, assess the current status of UAV photogrammetry online education, enhance the accessibility of online material, and empower learners and educators to make more informed choices.

2. OBJECTIVES AND METHODOLOGY

The increasing demand for reliable educational resources in UAV photogrammetry highlights the need to evaluate the current online landscape of courses, UAV datasets, and software tools. The EDU-UAV project, as part of the ISPRS Capacity Building Initiative 2024, aims to address this challenge by systematically analysing and categorising available resources, thereby bridging the gap between existing materials and user needs. This project focuses on creating a structured, open-access inventory that serves both academic and professional audiences. Additionally, it seeks to uncover the gaps in UAV photogrammetry education and its applications in geoscience through comprehensive surveys. The following subsections outline the objectives and methodology employed to achieve these goals.

2.1. Objectives

The goal of this project is to establish a comprehensive and interactive resource catalogue that covers online UAV photogrammetry education. The catalogue will classify courses based on various levels (introductory, intermediate, and advanced) and include information on available UAV photogrammetry software (both licensed and open source) and relevant UAV datasets. This resource will help learners and professionals better navigate the vast array of available educational materials. Besides, the project will gather insights into gaps in UAV photogrammetry knowledge areas and UAV applications in geoscience by designing and distributing the UAV Gap survey.

2.2. Methodology

The data for the catalogue will be collected systematically following predefined criteria using desk-based research and online surveys, ensuring that the collected information is categorised for easy retrieval. This will conclude the creation of an open-access website that serves as a central hub for educational support in UAV photogrammetry.

Mapping the current UAV photogrammetry educational landscape and identifying the gaps provides insights into current trends, challenges, and opportunities in this field and supports educators in designing strategies that bridge the gaps between available UAV resources and the growing demands. The project methodology is explained in Figure 1.

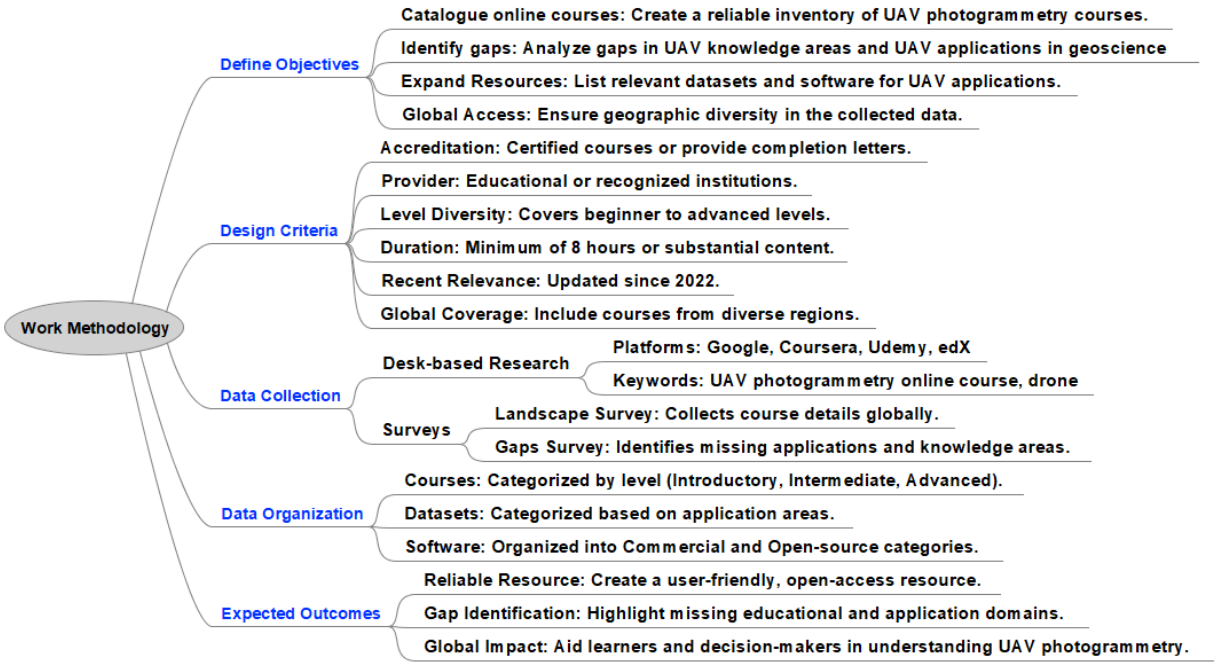

Figure 1. Work methodology

3. DESIGN CRITERIA

Given the substantial number of online courses available, it was essential to establish specific criteria to organise and collect UAV photogrammetry courses systematically. The design criteria were focused on ensuring that the resources gathered were relevant, up-to-date, comprehensive, and aligned with the project's goals. For UAV datasets and software packages, a more flexible approach was adopted to ensure the inclusion of resources that accommodate users with diverse interests, backgrounds, and needs.

Section 3.1 shows the specific criteria that were designed for the online courses. Section 3.2 explained the information to be collected for the courses, UAV data sets and the software packages.

3.1.Courses Collection Criteria

The following criteria have been used for course collection:

Criteria 1: Course Accreditation- The course is certified or provides a letter of completion, and it can be either credit-based or non-credit-based.

Criteria 2: Provider Institution- The course is offered by educational or non-educational institutions rather than an individual instructor. With this approach, we ensure the quality of the courses provided, as there are many online personal initiatives.

Criteria 3: Educational Level diversity- The collected courses will cover are categorised based on their educational level, including introductory, intermediate and advanced

Criteria 4: Course Duration- The course or series of sessions has a minimum duration of 8 hours or covers a substantial portion of the photogrammetric pipeline.

Criteria 5:

Recent Relevance: The course has been available or updated since 2022, ensuring that it reflects current developments and standards.

Criterion 6:

Geographic coverage diversity: the courses are collected globally to provide a general overview of the available courses worldwide.

3.2. Information collection overview

Related to the UAV online courses, the following information is aimed to be collected:

- Information related to the Institution, such as Institution Name and type of the Institution
- Information related to the course details such as Course Name, Course Description, course fees, and if it provided credits. Main Language or Languages, Delivery Method
- Information related to the educational content of the course, such as description, learning outcomes, knowledge areas or applications, knowledge prerequisites and the level of the course.
- Information related to the target participants, such as professionals or students.

Regarding UAV datasets, it was important to include descriptions and applications of each dataset to help users select the most appropriate resources that match their needs.

For UAV software packages, the focus was on selecting software packages dedicated mainly to processing UAV imagery for various applications. Besides, include both paid and free/open-source ones.

4. DATA COLLECTION

The ITC team employed various methods to gather information on available UAV photogrammetry online courses and identify

gaps in UAV education. Also, we compiled a list of UAV software packages, both licensed and open-source, and UAV datasets that can be used for training and educational development. A detailed explanation of the methods follows below.

1. Desk-based research

The desktop research for selecting relevant UAV courses involved three key steps. First, a Google search was conducted using keywords such as "UAV photogrammetry online course" and "UAV courses," but the results were limited. Second, the search was expanded to well-known academic platforms like Coursera, Udemy, and edX, using terms like "photogrammetry," "UAV," and "drone." Coursera yielded just one course that met the criteria, while Udemy provided several affordable options, though most were created by individual instructors and did not meet the desired standards. EdX offered a variety of courses and degrees from multiple universities, but only three relevant UAV courses were found. Finally, the search was extended to courses from top-ranked universities in Remote sensing according to the 2023 Global Ranking of Academic Subjects (Shanghai Ranking), but no relevant UAV application courses were identified due to language barrier or with most focusing on drone construction or navigation rather than photogrammetry.

For the documentation activity, we prepared an online form that consists of one sheet with the following fields and predefined categories, as shown in Table 1.

The authors documented 13 courses. Additional 1 course have been documented using EDU-UAV Photogrammetry Current Online Educational Landscape Survey as described in section 4.2.1.

The two lists of UAV software packages and UAV datasets were compiled through a desk-based approach. This process involved consulting various online specialised websites and relevant industry platforms. The team's collective expertise in UAV technology also played a significant role in identifying and verifying key resources, ensuring the lists were both comprehensive and up-to-date.

For the UAV datasets, information was gathered, including the name of each dataset, a description of its contents, the specific applications it supports, and a direct link to access the dataset. This structured approach will help users identify the most suitable datasets for their training and educational development needs. In total, 13 datasets were listed. The complete list of the UAV datasets can be explored on the website.

Similarly, the UAV software packages list was compiled with a focus on the name of each software, the company or organisation behind its development, and the company's headquarters location. Additionally, information was collected on the primary industries the software serves, allowing users to understand better the context and potential use cases for each package. Both licensed software and free/open-source UAV software were included to offer a wider range of options to the end users. In total, 12 software packages were collected. The complete list of software packages can be found on the website.

4.1. Survey

Two online surveys were also designed to collect information about the UAV photogrammetry online courses globally (section 4.2.1) and the gaps in UAV photogrammetry applications and education (section 4.2.2). The two surveys were conducted and later distributed on the EUSurvey. The EUSurvey is a web application created and managed by the Directorate General for Informatics of the European Commission, herewith known as "DIGIT".

Field	Description
Institution Name	The name of the Institution offering the course
Type of institutions	Educational Institutions, Research Institutions, Governmental Institutions, Profit/Private Institutions, and others.
Course Name	The name of the course
Course URL	The link to the website of the course
Duration and duration units	The duration of the course, including duration units such as hour, day, and month
Course fees	Including currency
Credits (ECTs)	The number of achieved ECTs (if any)
Main Language(s)	Main Language or Languages of the course
Delivery method	- Interactive: involves interaction time between the instructor and the participants, for example, via discussion boards or live-streaming lectures - Self-paced: no interaction between the participants and the instructors. Participants are independent and are provided with pre-recorded lectures and materials - For others, please specify
Course Description	The description of the course, including the description of the syllabus
Learning outcomes	The list of the learning outcomes of the course
Application fields	The main application field/s of the course such as agriculture, forestry, utilities, etc.
Knowledge Prerequisites	The prerequisite knowledge that is needed to enrol and excel in the course
Level of the target participants	- Beginners: individuals with no prior knowledge or experience - Undergraduate: individuals pursuing a bachelor's degree - Graduate: individuals pursuing a master's or doctoral degree - Professionals: individuals willing to enhance their knowledge and skills in a particular profession
The level of the course	- Introductory or foundational courses - Intermediate level including more depth and deeper understanding courses - Advanced or specialised courses
Remarks	Any additional information about the course

Table 1. Online Course Information Collection Form**.**

4.2.1 EDU-UAV photogrammetry online educational landscape survey

The online survey has been prepared to expand the geographic coverage and diversity of the collected information. Moreover, it captured insights into the transversal skills acquired through the identified DPs. The survey questions included close, multiple choice and short-answer questions. They were designed to be clear (showing examples for some) and direct, with a predefined list of answers (when possible) to receive more concrete/concise answers. The participants could also upload files or specify additional relevant websites. Only 2 questions were mandatory,

including the name and the course website. The survey was designed to maintain the anonymity of participants, ensuring that no personal data was collected.
The online survey is divided into three main sections:
- Section 1: Information about the course consisting of 11 questions.
- Section 2: Details of the respondent and Institution consisting of 3 questions.
- Section 3: Additional information and submission consisting of 2 questions.

The survey was shared on the ITC team's LinkedIn profiles and distributed to the ITC UAV centre email list.

4.2.1 EDU-UAV photogrammetry applications and educational gaps survey

The online survey was aimed at global coverage and diversity of the collected data. It consists of six questions: three addressing the participant's background, institution type, and location (continent), two focusing on gaps in applications and knowledge, and one allowing for additional comments or remarks. The survey included a mix of multiple-choice and short-answer questions and was structured to be completed in approximately two minutes. To ensure participant anonymity, no personal data was collected.
Appendix A shows the complete survey with all sets of questions. The survey was shared on the ITC team's LinkedIn profiles and distributed via email to ITC alums by the ITC Alumni Office. A total of 81 responses were received. However, two inputs were not included, one due to duplication and the other due to the irrelevancy of the survey, thus 79 respondents.

5. EXPECTED OUTCOMES

This section examines the current landscape of UAV education, including course providers, applications, and delivery methods. It also explores available datasets and software tools for UAV photogrammetry, highlighting their diverse applications across various industries. Finally, it applies the analysis of knowledge gaps in UAV photogrammetry based on a survey of professionals from different continents and institution types. This multi-faceted analysis provides valuable insights into the current state and future needs of UAV technology education and application.

5.1 Analysis of the courses

The courses listed–include several UAV-oriented courses being offered by universities and private entities specifically designed on organised areas ranging from photogrammetry to environmental sciences and precision agriculture. In the following, we introduce a brief analysis regarding key properties and key findings:

1. Course Providers
   - Universities: Educating institutions such as Wageningen University, University of Alaska Fairbanks, Duke University, and the University of Twente typically offer programmes with very academic orientation: these often stress scientific principles, real-world applications, and integration of UAVs into agricultural geospatial sciences and environmental monitoring.
   - Private Institutes: Some companies, such as Dart Drones, Drone Valk, and Pix4D, offer a more practical education, trying to match the needs of professionals in the industry sector.
2. Course Applications
   - Geospatial Science: Some courses related to UAV studies are offered within the University of Twente, which involve UAV-based photogrammetry, mapping, and geospatial applications.
   - Environmental Science and Monitoring: UAV applications for monitoring and data collection within various kinds of ecosystems are effectively addressed by "Drones for Environmental Science" at Duke University and another advanced sensing course from Wageningen University.
   - Agriculture: The domain of precision agriculture that works with UAVs concerning UAV sensing, hyperspectral imaging, and crop management is illustrated by Wageningen University, DroneValk, and the University of Twente.
   - Introductory UAV courses: Introductory courses such as "AlaskaX: UAS Fundamentals" introduce the UAV platform, the sensors, safety in flight, and basic applications.
3. Course Features: In general, the courses have the Learning Outcomes of understanding some important UAV applications (mapping, sensing, and visualisation), integrating sensors with UAV platforms for specific applications, and gaining practical skills in agriculture and urban planning.

   Apart from this, these courses quite generally focus on skill building.
   - Technical: Data acquisition, sequencing of flights, and operating UAVs.
   - Analytical: Data analysis, GIS, and photogrammetry.
   - Professional: Project design and UAV mission analysis
4. Course Audience and Prerequisite of the Course
   - Beginner: Depending on the course, the basics of the drone would vary as the courses "Drones for Environmental Science" or "UAVs in Precision Agriculture". However, this kind, of course, is for beginners or freshly graduated students who studied extensive basics of drones during the course.
   - Intermediate and Advanced: An advanced course from the University of Twente that would only help if a person had a former understanding regarding work in geospatial sciences or agriculture.
5. Delivery
   - The time duration of the course would vary from a few hours to a few weeks as some courses are hardly 6 weeks (about 1 and a half months) from Wageningen University, and some follow asynchronous learning type.
   - Asynchronous Learning: Coursera's, edX's, and Udemy's platforms provide flexibility for participants to finish the course at their own pace.
   - Hybrid Learning: Some university courses blend online content with face-to-face training sessions.
6. Certification: Completion certificates are awarded at the end of the course by the course providers, which can be important for job validation and professional development.
7. Cost: Some are offered freely; others are reasonably priced; however, those that are delivered by university faculties can be somewhat costly.

5.2 Analysis of the datasets and software packages

Different UAV datasets serve applications such as urban planning, agriculture, object detection, and disaster management. Each dataset offers good insights for specific areas of research and operational use. Researchers are responsible for selecting datasets appropriate to their project-related objectives, making sure the consideration of data type, resolution, and annotations is perfectly suitable.

The list of UAV photogrammetry software packages highlights a range of tools with diverse applications across various industries, including surveying and mapping, construction, agriculture, mining, and public safety. These software solutions from companies around the world cater to sectors ranging from large-scale industrial use to more flexible, smaller-scale operations.
Most of these software tools are paid licenses with varying pricing values, although many offer trial versions or educational versions for users. The last two options, OpenDroneMap and OpenSfM, are open-source and free, making them accessible to a broader range of users, including researchers and those working with limited budgets.

5.3 Analysis of the gaps

The distribution of the responses across the different continents and the type of Institution is represented in Figure 2 and Figure 3, respectively. The respondents are geographically distributed across Africa, Asia, Europe, and North America, with no representation from South America, Oceania, and Antarctica due possibly to fewer established connections in these regions. The responses were concentrated mainly in Africa (41.8%), Asia (31.1%) and Europe (21.5%), with significantly less participation from North America (3.8%).

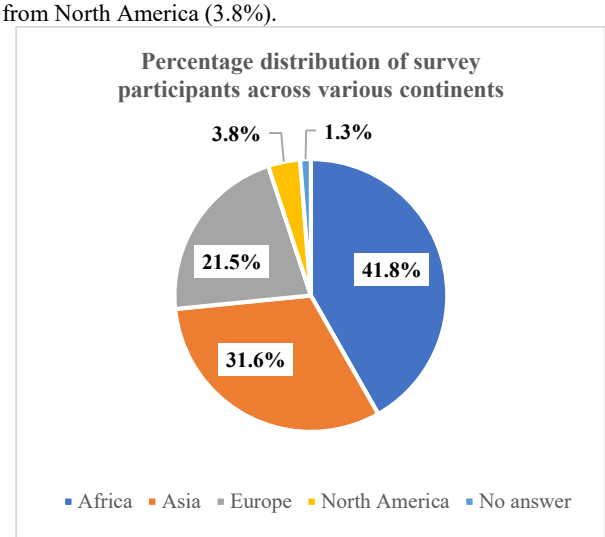

Figure 2. Percentage distribution of the survey participants across various continents.

Around 60% of the participants are affiliated with Educational Institutions such as Universities, Research, and colleges, while 16.0% are associated with Private or Individual institutes, and 23.5 % belong to Others. Based on the survey responses, most participants have backgrounds in geographic information science or relevant fields, remote sensing, environmental studies, natural resources management, and urban planning, among others. Their roles span a diverse range, including surveyors, PhD candidates, researchers, GIS professionals (both junior and expert), and engineers. As the survey targeted ITC alumni, some respondents indicated they were former ITC graduates. The responses highlighted the survey's effectiveness in reaching its intended audience, successfully bridging the educational and private sectors across different domains and career trajectories.

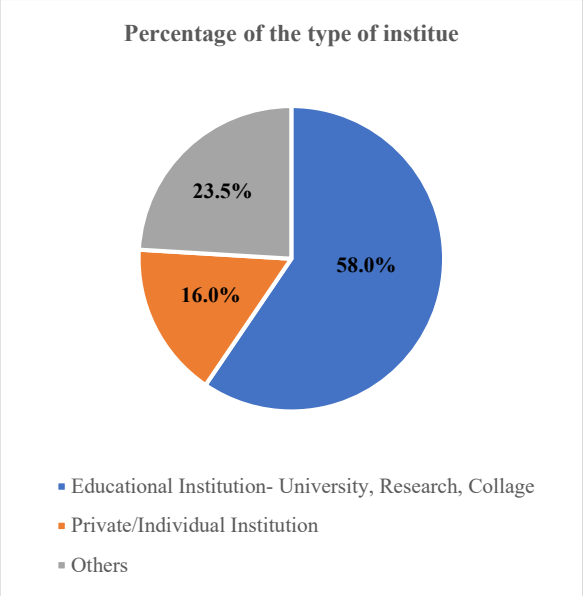

Figure 3. Percentage distribution of the responses across the different institution types

The survey contained one question related to the knowledge gaps in areas related to UAV photogrammetry. The question was a short answer, allowing the participants to write their input freely. However, that also adds a challenge to developing a quantitative constructive outcome. Thus, the team used the concepts from the EO4GEO Body of Knowledge (BoK) that were specifically developed to identify the foundational and interconnected concepts (theories, methods, and technologies) that characterized the Geographic Information and Earth Observation domain that need to be included in education and training programs. EO4GEO Body of Knowledge (BoK) is developed based on the Geographic Information Science and Technology Body of Knowledge (GI S&T BoK), which was established through the GI-N2K project in collaboration with the American University Consortium for Geographic Information Science., developed by the GI-N2K project based on the American University Consortium for Geographic Information Science. (EO4GEO,2018)
BoK starts from the super high-level hierarchy concept, Geographic Information Science and Technology, and then is categorised into more detailed concepts. For our task, we used the second hierarchy, divided into 14 sub-concepts, and manually assigned them to each response. We focused on the concepts that mainly related to earth observation. The Others-UAV operation and flight training concept was introduced as it was not covered in the BoK and received relatively high numbers of responses.
When a response included multiple sub-concepts, it was assigned to more than one category for accurate representation. Six responses were excluded due to the lack of clarity, such as history or software, representing an individual response.
Figure 4 shows the percentage of Knowledge areas lacking in the field of UAV Photogrammetry, based on the UAV Gap survey, analysed following the second hierarchy of the BoK and the introduced concept, with a total of 80 responses. The percentages highlight areas where there are gaps in knowledge or potential high demand, as identified by survey participants worldwide. . 28.8% of knowledge areas represented thematic and application domains spanning from environmental and natural resource management, including water, climate change and air quality, emergency, and disaster management focusing on flooding, surveying, and mapping, including indoor, cadastral and forest, and infrastructure and urban planning.

22.5% of knowledge areas represented image processing and analysis, focusing on machine learning, artificial intelligence, and computer vision. Advanced data processing and automation in data processing, field, and product generation, and multi-temporal data integration, including sensor and real-time data processing.
10.0% of knowledge areas represented platforms, sensors, and digital imagery, with a focus on the characteristics of diverse types of sensors and flight planning. 8.8% of knowledge areas were assigned to other UAV operations and flight training, with a focus on the practical aspects of flying drones, maintenance, and piloting.
1.3% of knowledge areas were assigned to GI and society, focusing on the ethical aspects of using UAVs. The same percentage is for Analytical Methods and Design and Setup of Geographic Information Systems, which are not directly connected to UAV photogrammetry.
26. 3% of the responses, representing the highest percentage, fall under the categories "None," "I do not know," or "No answer".
Besides, the survey included a question focused on identifying gaps in UAV applications and domains within Geo-information science. The question was a short answer, allowing respondents to list multiple applications. By reviewing the answers, seven application domains were identified and categorised based on their relevance, as illustrated in Figure 5. Furthermore, an additional category, "UAV Systems and Data Processing", is introduced to account for many responses related to knowledge areas rather than specific applications. Finally, Other Applications' is created to include responses that did not align with any of the identified categories. In total, we received 95 responses of applications and areas assigned to the various categories, highlighting the missing or potentially high-demand domains and applications identified by participants worldwide.

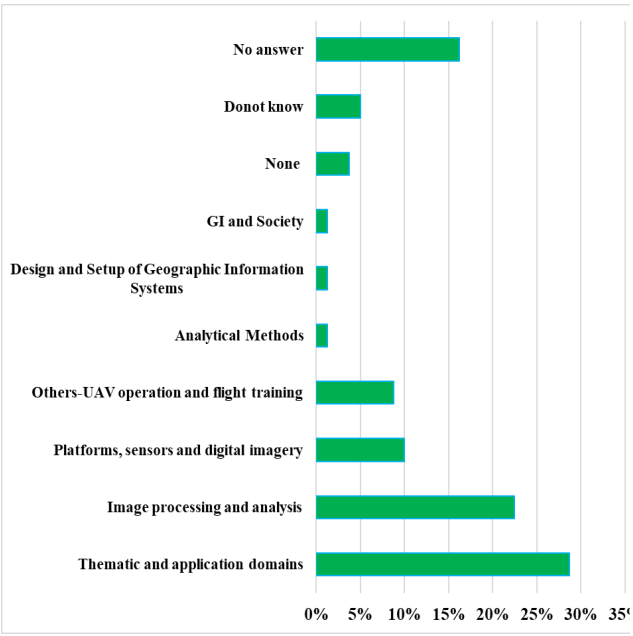

Figure 4. UAV Gap Survey results relative to knowledge areas lacking in the field of UAV photogrammetry

5.3% represented applications related to Agriculture and Farming with a focus on using UAVs for precision agriculture and crop health monitoring.
Security and Surveillance applications related to security, such as accident analysis and coastguarding. Furthermore, it can be linked to ensuring safety in accessibility and assistive services such as mapping, real-time monitoring, and obstacle detection for blind people, wheelchair users, and children with disabilities.
Emergency and Disaster Management applications have a 4.2% focus on real-time hazard assessment, natural disasters such as flooding and landslides and early warning systems. Besides, a small percentage of applications are related to Marine, such as spatial planning.
22.1% of the responses are related to the category "UAV Systems and Data Processing", emphasising the practical part of operating and flying UAV, capabilities or types of different sensors such as RADAR, and the area of photogrammetry, machine learning and artificial intelligence.

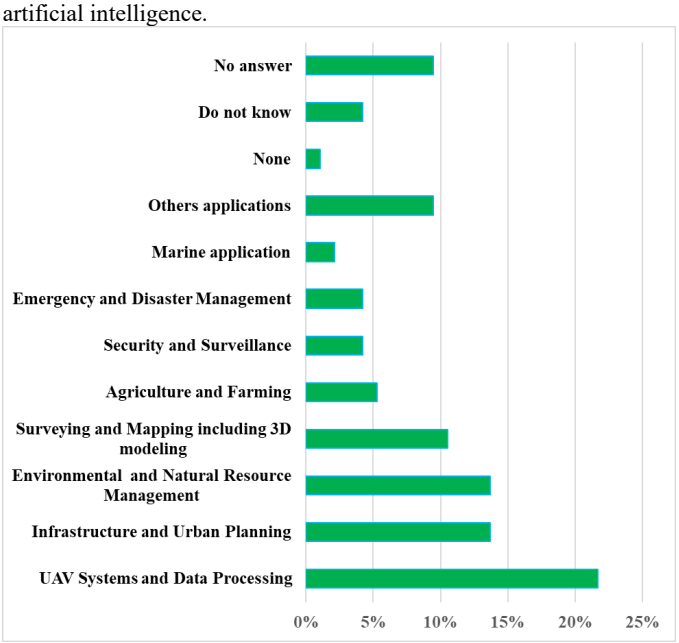

Figure 5. UAV Gap Survey results relative to UAV applications missing in Geo-Information Science

The Other applications category included geothermal fields monitoring, geophysics, metal detectors
mining, government services, legal aspects, finance, the link between soil, geology, and vegetation, and Monitoring applications.
14.7 % of the responses fall under the categories "None," "I do not know," or "No answer", which is lower than the first question.
The survey also included an open-ended question inviting respondents to provide comments or additional input. Out of 81 participants, only 14 responded. As the survey targeted ITC alumni, some respondents reflected on the courses provided at ITC or requested new ones in their country. Other responses were either irrelevant or highlighted that the survey was not easy or clear.
Some respondents reflected on the challenges faced in their countries, such as the high cost of the UAV photogrammetry application and the limited undergraduate programs in geospatial sciences or UAV-related fields. Data-related concerns included a historical lack of photogrammetry data, impacting government institutions' ability to create 3D models and point clouds. One respondent reflected on the geoinformatics field in general and emphasised the need to incorporate many fields, such as modern GIS skills, computer science applications, and innovative database models like TilesDB and DuckDB.

6. DISSEMINATION OF THE RESULTS

The project's outcomes will be delivered through a range of platforms and communication channels to maximise reach and

accessibility to the target audience. Our project's dissemination strategy aims to engage stakeholders across academia, industry, and professional communities interested in UAV photogrammetry and geoscience applications.

A compiled inventory of UAV photogrammetry online courses, datasets, and software packages is published on the ITC UAV centre as an open-access **website,** as shown in Figure 6. This will allow easy navigation by the user to search courses based on their levels, detailed descriptions, and categorization of datasets and software. To ensure continuous improvement, a feedback mechanism will be implemented on the open-access platform, allowing users to suggest additional courses, datasets, or software and share their experiences using the platform. This way, the resource will remain relevant and evolve with the needs of the community. By continuously updating the platform based on user feedback, it will remain a dynamic and valuable tool for those interested in UAV photogrammetry.

In addition, the ITC UAV centre will use social media like LinkedIn, Twitter, and Facebook to provide updates, display project outputs, and encourage contributions or feedback from stakeholders, ensuring broader engagement and effective dissemination of information.

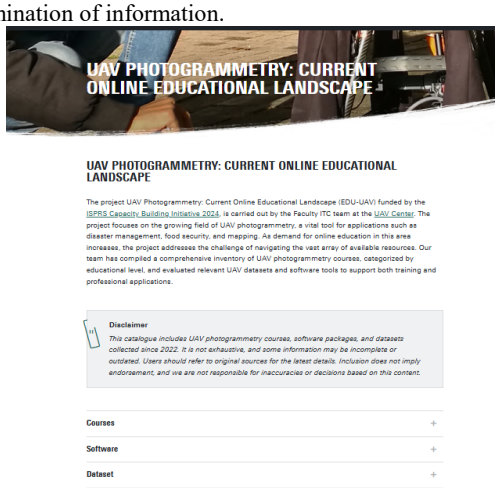

Figure 6. Screenshot of the project website showcasing the main interface and key features

7. CONCLUSIONS AND DISCUSSIONS

The project investigated the global landscape of UAV photogrammetry online courses and was extended to include free UAV datasets and UAV software packages. While a wide variety of software packages and data sets are universally accessible, the availability of online courses is quite limited, practically those developed by institutions offering certificates upon completion. Individual initiatives are extensively available, but their quality can be difficult to assess. On the other hand, many available courses focus on practical training and UAV design and assembling.

UAV Courses span a broad spectrum from the fundamental principles of UAV to specialised application areas, including agriculture, environmental monitoring, and geospatial sciences. The courses offer diverse learning needs for everyone from the beginner level to the experienced professional, and they can be free or inexpensive. In contrast, those providing certifications and university-run courses tend to be high-priced. Besides, the Courses offered are mostly integrated with real-world examples and case studies, which is very useful for professional participants.

Furthermore, online UAV courses are limited and variable in terms of their objectives, prior knowledge, and professional orientation. For example, beginners should easily start their careers with courses such as "Drones for Environmental Science" and "UAS Fundamentals" while advanced university courses offered by Wageningen University or the University of Twente would be a strong direction for those in the agriculture and geospatial sciences.

The survey responses are primarily concentrated in Africa, Asia, and Europe, with almost 60% related to Educational Institutions—Universities, Research, and Colleges—distributed almost equally across the three continents. The "Private/Individual Institution" and the "Others" categories, which may include government and non-profit organisations, focused on Africa. The survey showed global coverage and diversity but did not cover all continents, indicating the need for further investigation.

Some answers were brief in the survey, while others were more elaborated, providing a better understanding of the participants' perspectives. As the survey kept the participants anonymous, there was no possibility of following up with the answers, leaving some responses ambiguous to be excluded from the survey or interpreted to the best of our understanding. Besides, as the survey targeted the ITC alumni, some responses specifically reference the ITC course. Additionally, some responses were left unanswered, which may indicate gaps in knowledge or lack of clarity in the survey questions. Providing examples per question or multiple-choice questions with a predefined list of knowledge areas or applications could minimise the uncertainties.

The two close-ended questions confused the survey participants, leading to overlaps where applications were mentioned in the knowledge gap question and vice versa. By isolating and cross-checking the responses from both questions, it was observed that the dominant applications identified in the knowledge gaps aligned with the primary applications. In contrast, the key knowledge areas in the application question coincided with dominant knowledge gaps. This alignment demonstrates a harmonisation in the responses, providing reliability to the findings.

The survey outcomes are directly based on the collected responses, which still offer valuable insights into the gaps globally. The survey shows the need for UAV photogrammetry courses in different domains such as infrastructure and urban planning, environmental and natural resource management, emergency and disaster management, surveying, and mapping, that can utilise diverse knowledge areas in image processing and analysis using machine and deep learning, platforms and sensors also related to sensor integration and operating UAV.

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APPENDIX A

UAV GAPS SURVEY

EDU-UAV Photogrammetry Applications & Educational Gaps Survey

Fields marked with * are mandatory.

Introduction

As part of the ISPRS Capacity Building Initiative 2024, the University of Twente, Faculty of Geo-Information Science and Earth Observation, ITC Team at the UAV center aim to collect information about **Applications and Educational Gaps** related to UAV offered by universities and institutions globally**.**

Please note that the time required to complete this survey is **2 minutes.**

Please do not hesitate to contact (mailto:y.y.q.alasmar@utwente.nl) us if you have any questions. Thank you in advance for your contribution.

Q1 Please summarise your background using **2-3 keywords.**

***Q2** Please specify **the type** of the **institute** you are responding on behalf of.

- o Educational Institution- University, Research, Collage
- o Private/Individual Institution
- o Other

Q3 Please specify in which continent is your Institution primarily based.

- o Africa
- o Asia
- o Europe
- o North America
- o South America
- o Oceania
- o Antarctica

Q4 In your opinion, what are the **missing applications and domains** of UAVs in Geo- information science?

Q5 What **specific knowledge areas/topics** do you believe are lacking in the field of UAV photogrammetry?

Q6 Would you like to comment or add something else?

- o No, I want to submit.
- o Yes, I want to add.

Please specify:

Disclaimer!

The survey is designed to maintain the anonymity of participants. All the data provided will be handled confidentially, and the information will be published in an aggregated form that does not trace to individual entries. The analysis does not include any personal data, but in case you choose to share your personal information, it will be processed solely for purposes related to the project and in compliance with the General Data Protection Regulation (GDPR).

Contact

Contact Form (/eusurvey/runner/contactform/32747edf-98fe-25f2-0b8f-09d5e340841b)