NAVIGATING THE BUILT ENVIRONMENT: A COMPARATIVE STUDY OF UAV AND WEB-BASED 3D MODELING TECHNOLOGIES

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ABSTRACT

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have emerged as a transformative technology within urban management as an aerial photography tool that presents novel avenues for refining digital twin creation, fostering public engagement, and deepening comprehension of the built environment. This study examines the accuracy of 3D models produced through UAV photogrammetry in contrast to web-based 3D models. By doing so, it interprets the consequential impact of such variances on their adaptability across diverse urban and regional planning tasks. Discerning each approach's distinct merits and demerits, the research identifies optimal contexts for their respective deployment. In addition, the paper addresses the limitations intrinsic to UAV deployment in urban and regional planning. These insights pave the way for innovative avenues in 3D model construction that amplify public engagement and involvement, thereby cultivating a more inclusive and informed planning paradigm.

BIOGRAPHICAL SKETCH

Dingkun Hu grew up in Hangzhou, China. He graduated from the University of Illinois at Urbana-Champaign with a bachelor's degree in urban studies and planning in 2022. Continuing his academic journey, he studied city and regional planning at Cornell University and joined the Just Places Lab directed by Professor Jennifer Minner. His studies at Cornell have exposed him to diverse topics such as Urban Simulation, Engineering Smart Cities, Public & Spatial Economics, and Graphic Communication.

After completing his Master of Regional Planning at Cornell University, Dingkun will join the School of Architecture at Georgia Institute of Technology as a PhD student, where he will specialize in Urban Building Energy Modeling (UBEM). His research will focus on informing design decisions on electrification to eliminate energy cost burdens, increase regional energy resiliency, and develop innovative solutions to counter the disproportionately adverse impact of climate change on urban communities.

Dedicated to my younger self and to the guiding lights who made the journey enjoyable.

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INTRODUCTION

The rapid development of cities has led to a three-dimensional urban environment characterized by an increasing number of high-rise buildings and growing complexity in urban form. However, the traditional methods of urban planning and mapping have remained rooted in two-dimensional line drawings derived from basic surveying and mapping technologies such as satellites and airplanes (Koc et al., 2020). These conventional approaches, reliant on flat maps, lack the intuitiveness and richness of data required for contemporary urban construction and planning. In contrast, the adoption of three-dimensional (3D) data offers a transformative shift, providing intuitive, data-rich insights into urban landscapes (Park & Ewing, 2017). As a result, 3D city modeling has emerged as a potent tool that may gradually supplant two-dimensional data in the realm of urban planning and construction.

Generating 3D models for urban planning requires leveraging various data sources, including satellite imagery and close-up photogrammetry data (Xu et al., 2016). However, these methods often struggle to consistently produce high-quality 3D models. UAV tilt photogrammetry is emerging as a promising solution as it offers several advantages. For instance, it provides a medium coverage range, enabling detailed modeling of urban areas. Moreover, UAV tilt photogrammetry boasts rapid modeling capabilities and superior precision compared to satellite and other airborne technologies (Watts et al., 2012; Zulkifli & Tahar, 2023).

While the initial investment in UAV equipment and operation can be significant, the cost-efficiency of data acquisition through UAV tilt photogrammetry can outweigh these expenses in certain scenarios (Park & Ewing, 2017). For instance, in cases where high-resolution and accurate 3D models are critical for decision-making in urban planning, the upfront costs may be justified by the long-term benefits. Additionally, while freely available platforms like Google Earth provide valuable data, they may lack the level of detail and precision required for comprehensive urban modeling and analysis. Therefore, despite the initial investment, UAV tilt photogrammetry remains an attractive choice for generating high-quality 3D models in urban planning contexts.

This paper summarizes a comprehensive comparative analysis, systematically evaluating the effectiveness of UAV-based 3D models in contrast to other existing 3D models. Through meticulous examination, this study aimed to gauge the accuracy and level of detail achieved by UAV-derived models, particularly emphasizing their suitability for rendering and design applications in urban contexts. The guiding questions addressed in this research are:

- Compared to web-based 3D models, can UAV 3D modeling efficiently enhance the understanding of building stock and the environment?
- What are the distinct advantages and disadvantages associated with UAV-generated 3D models and web-based 3D models, and how do these differences influence their suitability for various urban and regional planning tasks? In what specific scenarios does one method outperform the other in terms of accuracy and applicability?
- How can researchers leverage the fusion of UAV-generated 3D models and web-based 3D models to influence public policy, and what strategies can be employed to maximize the value of youth engagement in shaping public policy and decision-making processes related to preservation and building material reuse, with a specific emphasis on leveraging drone 3D models?

To address these questions, a comparative analysis was undertaken, pitting UAV-based 3D model of a historical site against other available 3D models, specifically, Google

Earth and ArcGIS OpenStreetMap, assessing their accuracy and level of detail. Additionally, this research paper provides a comprehensive process guide for future researchers looking to create 3D models for analysis.

To begin, this paper provides an overview of the current landscape of UAV technologies and systems, setting the stage for a comparative examination. Following this, this paper delves into the application of UAVs in mapping urban areas, highlighting their unique advantages and addressing limitations in comparison to other methodologies. Subsequently, the paper details the methodology of our empirical research, which encompasses background analysis, methodological considerations, the variety of UAVs employed, flight planning strategies, geographical factors, and camera calibration techniques. Furthermore, the paper discusses the nuances of image acquisition for surface reconstruction, exploring the software tools utilized for generating dense point cloud models, crafting digital surface models (DSMs), and evaluating the accuracy of feature extraction. Throughout this exploration, this research paper compares these methodologies based on key parameters, including accuracy and precision, cost-effectiveness, and possibilities for public participation and engagement. To enrich the analysis, the paper will draw upon insights from a youth program I participated in, leveraging youth perspectives to provide a comprehensive assessment of the methodologies under consideration. Lastly, the paper synthesizes the study’s findings, underlining the significance of UAV mapping and 3D modeling in urban space management and providing insights into future directions based on our research outcomes.

The research serves a triple purpose. Firstly, it outlines an alternative, cost-effective, safe, and precise method for gathering building information data and environment characteristics of the surrounding area, using New York State Inebriate Asylum as a case example. Specifically, the study investigates the utilization of unmanned aerial vehicles (UAVs) to capture images documenting the built environment. The employment of UAVs enables more frequent collection of building data and 3D models, complementing and potentially enhancing material reuse evaluation, on-site assessments, and virtual tools such as Google Street View. This data is of utmost importance for scientific research aiming to deepen our comprehension of the accuracy of UAV-enabled 3D modeling. Secondly, the collected data is compared with more widely accessible sources like satellite and street imagery. Finally, the research addresses the practical difficulties, limitations, and issues related to data quality that arise when implementing a UAV-based approach.

Furthermore, this research project closely aligned with the endeavors of Cornell Undergraduate Research-To-Action Youth (CURTA-Y), an innovative initiative that engaged youth in the realms of UAV imagery and 3D modeling in fall 2023. CURTA-Y is a student organization incubated by researchers in the Just Places Lab at Cornell University to mobilize high-school students from South Central New York. Their collective objective is to embark on a comprehensive evaluation of detrimental demolition practices while concurrently exploring alternative strategies, such as deconstruction. This mission is underscored by a commitment to addressing pressing environmental injustices and community needs. Within the context of this collaborative venture, there existed a distinct and promising opportunity to enhance the youth engagement project. Thus, I participated in a demonstration of drone photogrammetry and 3D modeling, aimed at adding a valuable educational component for the young participants. This demonstration aimed to empower students with the knowledge and practical skills pertaining to cutting-edge technologies while simultaneously enriching their educational experiences.

By introducing high school students to the intricacies of drone photogrammetry and 3D modeling, this research sought not only to contribute to students' personal and academic growth but also to equip them with tools to delve deeply into urban and environmental issues. This interdisciplinary approach not only enhanced the research experience for the students but also augmented the overall quality and depth of the project's findings. Therefore, this research grew beyond its original aim to compare technological methods, but also to help evaluate the ways this technology could help youth to actively engage in the assessment and remediation of environmental challenges in their communities. The integration of UAV imagery and 3D modeling served as an educational catalyst, allowing young people to explore emerging technologies while equipping them to be active participants in addressing critical urban and environmental issues within their region.

Figure 1. Demonstration of UAV 3D modeling

APPLICATION PRINCIPLE AND PROCESS

The integration of UAV 3D technology with building information modeling tools offers new opportunities for the application of scientific methods and greater precision in urban planning. This convergence of drone technology and architectural tools can benefit urban planning and historic preservation (Sestras et al., 2020). However, successful implementation of UAV 3D modeling and other drone technologies in urban planning relies on adhering to industry norms and standards and integrating with other relevant technologies. Therefore, the following principles and processes must be followed to ensure the effective use of drone technology in urban 3D modeling and planning, based on existing research and practical experience.

2.1 Application Principle

The widespread adoption of UAV technology has been facilitated by advancements in UAV 3D modeling, which is a crucial tool for effectively capturing and analyzing real-world data in 3D. Real-scene 3D modeling provides urban planners with comprehensive information resources, enabling thorough data analysis, and leading to improved urban governance, optimized resource utilization, and enhanced urban management services (Liang et al., 2017). To ensure successful implementation in the urban planning industry, the application of UAV 3D modeling should adhere to the following principles:

From vertical photography to oblique photography

UAV tilt photography is a high-tech technology in the field of surveying and mapping. Unlike the conventional vertical photography method, tilt photography captures images from various angles, providing a more comprehensive and accurate view of the urban environment (Lienard et al., 2016). Equipped with a vertical lens and four tilt lenses, each sensor collects ground image information from multiple angles, providing detailed information about the cityscape. The images captured through tilt photography can provide a more realistic representation of the urban environment, potentially enabling better decision-making in urban planning and management. Moreover, the integration of tilt photography with other remote sensing technologies, such as LiDAR and hyperspectral imaging, can further enhance the quality of the data collected and provide a more complete understanding of the urban environment (Barba et al., 2019).

From 2D plane to 3D space

The conventional two-dimensional planning method is becoming outdated and is struggling to meet the evolving demands of urban planning. Those limitations have resulted in the emergence of new spatial information technologies such as UAV aerial photogrammetry, real-scene 3D modeling, and 3D GIS, which offer new approaches to urban planning. By collecting image data through UAV aerial photography and using specialized software to process and store real 3D models of the city, urban planners can now advance from 2D to 3D applications. The 3D digital model can simulate and preserve the 3D landscape of the site, extract valuable site information, and provide support for urban planners to make informed decisions (Siebert & Teizer, 2014). This enhances the accuracy of planning and design, as well as the efficiency of planning management. Therefore, UAV technology serves as a powerful tool for measuring the 3D structure of urban spaces, both for historical and future planning purposes. The use of UAVs in urban planning can transform the planning process, leading to more effective and efficient planning outcomes. For example, urban planners can use UAV-captured 3D models to visualize and analyze potential development projects, assessing their impact on the surrounding environment, infrastructure, and community.

Additionally, UAVs facilitate more detailed reviews of the built environment, whether existing or proposed in development proposals. This allows planners to accurately assess factors such as building heights and setbacks, enabling them to make informed decisions that balance development goals with environmental sustainability and livability. By leveraging UAV technology, urban planners can optimize land use, improve infrastructure design, and create more resilient and vibrant urban spaces.

From manual modeling to machine modeling

The use of UAV tilt photography technology leads to a significant reduction in the cost and time of manual modeling, making it a valuable tool for urban planning (Banfi et al., 2023). The 3D model created using UAVs and real-scene 3D modeling technology provides a comprehensive understanding of the current situation of urban planning and helps planners compare different planning scenarios (Tan & Li, 2019). This information can be used to analyze urban structures and make informed decisions, with the potential for more efficient planning and better urban outcomes (Zhou et al., 2022). UAV 3D modeling technology is not only applied in urban planning, but also in other industries such as smart cities, urban construction, and urban transportation. By providing a deeper understanding of the urban landscape through analysis of the skyline, sensitive points, and field of view, UAV tilt photography technology has proven to be a critical tool for advancing the urban planning industry.

2.2 Application process

To fully realize the potential of UAV technology in urban planning, it is important to consider the following three directions for its application: Firstly, UAV aerial photography should be combined with other technical media, such as ground photography, surveys, and other relevant data collection methods, to obtain more comprehensive datasets. Secondly, spatial data should be integrated with other forms of data, such as floor plan data, to create a 3D virtual model that incorporates various aspects of the urban environment. Thirdly, planning analysis, integrated analysis, and strategic analysis should be combined to provide a systematic evaluation of the urban environment. This includes location and transportation analysis, landform analysis, architectural analysis, ecological analysis, humanistic analysis, and economic and social analysis (Liang et al., 2017). The goal of this approach is to generate both three-dimensional system outcomes and planning element outcomes that can be used for decision-making purposes (Lienard et al., 2016). By following these directions, urban planners can leverage the benefits of UAV technology to enhance their understanding of the urban environment and create more effective planning strategies.

Despite its potential benefits, the integration of UAV technology in urban planning, particularly in urban 3D modeling, has not yet seen significant progress. One of the primary reasons for this is the lack of understanding and expertise in UAV control and operation among planning and preservation practitioners, as well as researchers (Hu & Minner, 2023). Many are unfamiliar with flight parameter setting, flight operation, and the generation of spatial data and 3D models. Therefore, to fully harness the potential of UAV technology in urban planning, it is essential to establish a comprehensive approach. Drawing on current research and practices, this section outlines a fundamental technical scheme and pathway that includes the following key components.

Regional aviation survey

Before conducting the survey, careful consideration is given to selecting the appropriate UAV equipment, considering factors such as payload capacity, flight endurance, and sensor capabilities to ensure optimal data collection and analysis. The use of UAV technology in urban planning surveys requires the initial determination of the aviation survey area, followed by a preliminary survey. Then, a detailed investigation of the residents, buildings, climate, roads, and altitude in the survey area is conducted, and a reasonable survey scheme is formulated through the survey to prepare for flight.

Determine flight parameters

To obtain data using UAV aerial photography, the flight route is determined based on the shape of the study area. Then, parameters are set according to the aerial photography area. A special camera with a wide-angle lens is installed on the UAV, and the camera's parameters are adjusted to correct the pixels and resolution. An RTK measuring instrument is used as an auxiliary tool.

UAVs are utilized for aerial photography, capturing high-resolution images with special cameras. GPS navigation and remote-control technology are employed to command and control the UAVs, enabling them to fly along a specific line at a predetermined speed and capture images. To enhance the UAV's efficiency and autonomy, flight platforms and autopilot systems can be utilized to program, coordinate the route, and photograph the mission before the flight (Liang et al., 2017). These capabilities make UAVs invaluable for various applications such as land use mapping, infrastructure inspection, environmental monitoring, disaster assessment, agriculture, search and rescue operations, and cinematography, expanding their potential across multiple industries.

Data generation and inspection

To ensure the effectiveness of UAV aerial photography, it is crucial to record, sort, and check the relevant image data after completing the aerial photography. The UAV's camera and GPS system function simultaneously, recording the image location and time under the image attribution. Commercial software, such as Pix4D Mapping and 3D modeling packages, can collaborate seamlessly with drones and automatically create models. Output also works with AutoCAD, and this data can be easily organized and used to generate 3D models (Pix4D LLC, Swiss) (Liang et al., 2017). Systematically setting up data collection procedures to capture this metadata lays the foundation for complete analysis.

2.3 Technical route

UAV aerial photography produces flight data and images, but they require additional processing to be useful. Image processing software can be used to analyze and process these data, creating virtual panoramas, related models, and coordinate graphs (Luo et al., 2022). In urban planning, the integration of UAV tilt photography and 3D modeling technology is the technical route. Through data and image processing, virtual panoramas and 3D models are generated, and 3D building information models are created. A 3D auxiliary planning platform can be used to upload and share 3D simulated schemes online, enabling the comparison of multiple schemes. The three-dimensional real-scene model provides a comprehensive view of the city and helps to select a planning scheme that meets the conditions and fits the surrounding architectural environment. Combining bird's-eye view rendering reports with 3D models can improve the understanding of the project and surrounding conditions, including analysis of route planning, visual domain, building height, and other information (Parikh et al., 2022).

RECENT STUDIES

Recent literature on Unmanned Aerial Vehicles (UAVs) highlights their integration with imaging technologies for spatial mapping and 3D modeling, showcasing diverse applications in urban planning, disaster assessment, archaeology, and ecology. This review aims to synthesize recent studies, focusing on accuracy assessment, comparisons with satellite imagery, disaster response, urban regeneration, and participatory decision-making. By exploring these themes, we provide insights into current research trends and future directions in UAV-based spatial mapping and 3D modeling.

UAVs offer a means to collect hyper-local ecological information crucial for understanding neighborhood conditions and their impact on social processes (Grubesic et al., 2018). Utilizing UAVs to gather detailed data on physical disorder, aesthetics, and pedestrian safety enables researchers to connect place-based factors with broader social, criminological, and public health phenomena. However, operational challenges and data quality issues must be addressed to realize the full potential of UAV-based approaches in urban research.

The use of UAVs for 3D reconstruction presents opportunities for efficient data acquisition and analysis, particularly in post-disaster scenarios (Nagasawa et al., 2021). By employing multi-UAV coverage path planning methods, researchers can reconstruct damaged buildings with higher resolution and detail, enabling accurate damage assessment and decision-making (Zhao et al., 2021). Such methodologies leverage UAV technology to provide detailed insights into disaster-affected areas, complementing satellite imagery with localized, high-resolution data.

Advancements in video resolution, particularly with ultra-high-definition (UHD) cameras, present opportunities for enhancing image-based 3D city modeling. Alsadik and

Khalaf explored the potential benefits of using UHD videos, particularly from consumer-grade drones, for generating highly detailed 3D point clouds with low noise. The study quantifies the expected improvements in 3D models and point cloud density, showing substantial enhancements in relative accuracy and point density with UHD videos compared to lower-resolution counterparts (Alsadik & Khalaf, 2022). Such advancements hold promise for various applications in geoinformation science and photogrammetry.

The integration of Unmanned Aerial Vehicles (UAVs) equipped with tilt photogrammetry platforms has garnered significant attention due to its potential in constructing precise 3D models efficiently. Chen et al. focus on assessing the accuracy of such models in a specific urban area. By employing UAV imagery to capture images of the playground and library of the Department of Informatics of Wuhan University, the study evaluates the spatial accuracy of the resulting 3D model, and the findings reveal centimeter-level accuracy, indicating the suitability of UAV-based tilt photogrammetry for generating reliable data support for construction and urban planning industries (Chen et al., 2022).

Satellite imagery from platforms like Google Earth has been extensively utilized for various applications, including archaeological site identification. In a study by Kaimaris et al., the capacity of Google Earth satellite images in identifying new archaeological remains is examined. Focusing on the Eastern Macedonia region in Greece, the research employs systematic selection processes of satellite images alongside other archaeological predictive tools (Kaimaris et al., 2011). This approach leads to the detection of numerous new archaeological sites, demonstrating the efficacy of Google Earth imagery in archaeological research.

The advantages of satellites over drones include autonomy, accessibility, consistency, scalability, and price considerations (Satish, 2021). Satellites operate autonomously once in orbit, enabling consistent data collection over time without the need for manual operation. They provide accessibility to remote or inaccessible areas without the limitations of drone range or operational complexities. Furthermore, satellite imagery offers consistency and scalability, making it suitable for large-scale applications such as change detection and monitoring (Fytsilis et al., 2016). Additionally, satellite imagery tends to be more cost-effective due to lower operational costs and decreasing prices driven by advancements in satellite technology and increased competition among space companies.

The utilization of UAV technology for aerial mapping and 3D modeling has gained traction as a cost-effective alternative for localized mapping projects. Qin et al. describe a UAV mission aimed at generating a 3D model of the National University of Singapore (NUS) campus. Despite challenges posed by urban environments with high-rise buildings and dense vegetation, the study demonstrates the feasibility of UAV-based 3D modeling using a lightweight platform (Qin et al., 2013). The research underscores the importance of selecting appropriate UAV platforms and data processing techniques for achieving high-resolution 3D models with textured surfaces and accurately modeled infrastructure.

Conversely, drones offer advantages in quality imaging, precision, ease of deployment, and security (Satish, 2021). Drones can capture high-resolution images and videos with precision due to their proximity to the ground and GPS-guided deployment. They are easily deployable and maneuverable, making them suitable for various applications, including security and surveillance. Moreover, drones can provide detailed information in areas inaccessible to traditional methods, such as dense forests or swampy terrain. This capability makes drones particularly valuable for tasks requiring detailed, localized data collection, such as post-disaster damage assessment (Nagasawa et al., 2021).

The integration of UAVs into urban spatial mapping processes holds promise for enhancing the understanding of urban environments and facilitating participatory decision-making (Skondras et al., 2022). By collecting quantifiable and qualitative information through UAV-based 3D modeling, researchers can gain insights into urban dynamics and engage citizens in local decision-making processes. This approach enables the exploration of alternative strategies for urban regeneration and the assessment of their implications on the built environment.

Overall, the literature underscores the diverse applications and advantages of UAV-based 3D modeling, ranging from urban planning and construction to archaeological research. While studies highlight the accuracy and efficiency of UAV-based approaches, they also acknowledge challenges related to environmental factors and data processing techniques. These insights inform the ongoing exploration and refinement of UAV technologies for generating reality-based 3D models and advancing various fields of research and practice. In summary, the integration of satellite and UAV technologies offers complementary advantages for spatial mapping, disaster assessment, and urban research. While satellites provide broad coverage and consistency, drones offer localized, high-resolution data collection capabilities. By leveraging both technologies effectively, researchers can enhance their understanding of urban environments and contribute to informed decision-making processes for urban development and regeneration.

In addition to the benefits, it is crucial to acknowledge the limitations and challenges associated with the use of UAV technology in urban research and planning. Restrictions on the use of drones in certain areas, such as densely populated urban centers or near airports, pose significant operational challenges and regulatory hurdles. Moreover, obtaining permissions for UAV operations can be prohibitively expensive and time-consuming, particularly in cities with stringent regulations like New York City (Hu & Minner, 2023). Privacy concerns also loom large, as UAVs equipped with cameras raise questions about surveillance and data privacy. Ensuring compliance with privacy laws and regulations while conducting aerial surveys and capturing imagery becomes paramount in maintaining public trust and upholding ethical standards. Furthermore, environmental factors such as weather conditions and airspace congestion can affect the feasibility and safety of UAV operations, potentially limiting their effectiveness in certain situations. Despite these challenges, ongoing advancements in technology and regulations are gradually addressing some of these issues, paving the way for more widespread and responsible use of UAVs in urban research and planning. By carefully navigating these limitations and adopting best practices, researchers can harness the full potential of UAV technology while mitigating its associated risks and concerns.

However, despite the wealth of research in this area, there remains a gap in understanding the comparative advantages and limitations of different approaches, particularly in the context of urban regeneration initiatives. This presents an opportunity for this paper to make a significant contribution by addressing key questions and conducting a comparative analysis. By filling this gap and offering valuable insights into the practical applications of UAV technology for urban spatial mapping, this research aims to advance the understanding of UAV-based 3D modeling and its role in shaping the future of urban development and sustainability. Furthermore, the collaboration with Cornell University

Research-To-Action Youth (CURTA-Y) adds a unique dimension by empowering young participants to explore cutting-edge technologies and actively contribute to addressing environmental justice and preservation challenges in their communities, fostering meaningful engagement and inspiring future generations of urban planners and environmental stewards. Hence, this paper holds promise for advancing the understanding of UAV-based 3D modeling and its implications for urban development and sustainability.

MATERIALS AND METHODS

4.1 Study Area

The New York State Inebriate Asylum was selected as the modeling object because of its unique architectural design and long history. The asylum holds national significance in the field of health and medicine as it was the first hospital in the United States to be designed and constructed specifically for the treatment of alcoholism as a disease. It emerged as a result of changing American attitudes towards alcohol between the Revolution and the Civil War, with the temperance reform movement gaining momentum and political power (U. S. National Park service, n.d.). The significance of the building lies in its historical role in medicine, particularly in its use of the Kirkbride plan which called for the segregation and classification of patients based on gender and severity of illness. This plan is reflected in the building's design, with administrative functions at the center and patients housed in long flanking wings. The New York State Inebriate Asylum is nationally significant under Criteria A and C (U.S. National Park service, n.d.). Despite its historical significance and status as a National Historic Landmark, the building has been abandoned since its closure and is currently listed as one of New York State's Most Endangered Buildings.

This paper also presents how aerial photogrammetry enables documentation of artifacts at risk of submersion to support historic preservation efforts to mitigate the effects of disasters. Creating a 3D model of the New York State Inebriate Asylum can provide numerous benefits. First, a 3D model can help to accurately document the current state of the asylum, including any areas that may have deteriorated over time. This information can be useful for restoration and preservation efforts, as well as for historical research. Second, a 3D model can be used to explore the asylum's original design and layout, which can provide insights into the treatment methods and philosophies of the time.

Overall, creating a 3D model of the New York State Inebriate Asylum can provide valuable insights into the history of healthcare and institutional design, as well as lay a foundation for future urban 3D modeling for urban and regional planners. By accurately documenting the asylum and its layout, researchers can help ensure that its historical significance can be preserved for future generations, which can be used to inform the design of modern healthcare facilities and other public spaces.

4.2 Hardware platform

For the case study presented in this paper, low-altitude aerial images were captured in a single flight using a DJI Mavic 2 PRO UAV platform, equipped with a Hasselblad 4/3 CMOS camera and a global navigation satellite system (GNSS). The UAV was operated to take aerial images of the study area together with a third-party program “Altizure”, and a Sony A7 Mark III equipped with a 28-200mm lens was used to take ground photos. The flight was conducted at an approximate altitude of 50 meters with a 100-meter radius from the center of the study site. As this UAV has no real-time kinematic (RTK), multiple overlap images will be taken to minimize the offset.

4.3 Flight Planning and Image Acquiring

Before the flight, a calibration process was conducted to ensure that all equipment, including UAVs, remote controllers, and computers, was functioning properly. This was done to prevent crashes and system failures that could result from equipment malfunctions. The calibration phase was conducted meticulously to confirm that the UAV was operational and prepared for take-off. The study also followed a strict pre-mission procedure of checking and adjusting camera settings for both the DJI MAVIC 2 PRO camera and the terrestrial DSLR camera. This was done to ensure the quality and usefulness of the collected data and to save time in the long run. We checked three main camera settings: exposure, temperature, and focus, settings were adjusted accordingly. For the terrestrial cameras, exposure was adjusted manually, which required constant corrections and adjustments as the lighting changed. We gave preference to adjusting shutter speed and aperture over ISO to avoid losing photo quality or introducing blur.

The UAV was connected to the software using a radio transmitter to enable automated flight. However, for safety reasons, the take-off and landing were manually executed via the remote controller. Once the UAV was airborne, the software took over the automated flight mode. Throughout the flight, the UAV pilot was able to monitor the aircraft's position on the software, as well as data such as acceleration, speed, and navigation.

In addition to the pre-mission camera check, we periodically stopped and checked data in the field to ensure image quality and make necessary adjustments. The drone camera was checked before each flight using the app focus setting. We also made an effort to capture images at as close to the same time as possible to ensure consistency. Grid flights were conducted at the beginning of each mission and drone images were ideally taken alongside terrestrial images. The entire data acquisition process took about one hour, and each flight lasted approximately 20 minutes. Batteries were changed for the second flight deployment. A total of 400 geotagged images were obtained for this study, with an 80% overlap between them.

To ensure that the modeling software ContextCapture could recognize the same key points as tie points between images, we focused on having significant image overlap and similar ground sample distance (GSD) between terrestrial and UAV images. We also worked to close the gap between aerial and terrestrial photo locations by flying the UAV at increasingly lower altitudes or even carrying it by hand to achieve the desired image overlap.

4.4 Geoprocessing

The real-world 3D modeling software used in this study is ContextCapture, formerly known as Smart3D from Acute3D, a fully automated 3D modeling software that generates ultra-high density point clouds using continuous multi-angle imagery without human intervention, and on this basis generates high-resolution 3D scenes with realistic image textures. The software was used to process the acquired geo-tagged images on a Windows-based laptop equipped with an Intel Core i7 processor at 5.1 GHz, 32 GB of RAM, and an NVIDIA GeForce RTX 2080 Super graphic card. The processing time for creating the orthomosaic in ContextCapture was 41 minutes, but the outcome achieved was of exceptional quality. After that, the 3D model was exported and analyzed in detail.

4.5 Web-based 3D models

In this section, I explore the utilization of web-based 3D modeling tools for comparative analysis. Google Earth was chosen as the primary platform due to its global coverage and intuitive user interface. This choice was made to leverage the widespread accessibility and user-friendly features that Google Earth offers as a visualization tool. This assessment scrutinizes the precision and level of detail provided by Google Earth, highlighting its strengths and potential limitations. To ensure robustness, I also employ Google Maps as a supplementary tool for cross-verifying measurement data.

The second selection in the realm of web-based 3D modeling is ArcGIS OpenStreetMap. With its robust geospatial capabilities, ArcGIS OpenStreetMap presents a dynamic mapping solution that caters to the needs of planning researchers and industry professionals alike. This analysis seeks to unveil the accuracy and granularity of its 3D model, shedding light on its suitability for a broad spectrum of geospatial applications.

Additionally, I attempted to use CAD Mapper along with SketchUp Pro to create a 3D model of the site. Unfortunately, CAD Mapper did not have the necessary geographic data for our chosen site. As a result, I could not generate the intended 3D model using this tool. It is worth noting that issues were encountered with web-based models accurately identifying building surfaces. This led to inaccuracies in measurements, as the selected dot would move around vertically rather than staying in the intended spot. Therefore, I opted to measure the length of building edges vertically instead.

RESULTS

5.1. UAV vs satellite imagery

To comprehensively assess the quality of imagery acquired from Unmanned Aerial Vehicles (UAVs), one valuable approach involves a comparative analysis with widely accessible and frequently viewed satellite imagery, which is readily available to the public. As illustrated in Figure 1, one can readily access satellite imagery through user-friendly platforms such as Google Earth and Google Maps.

However, Figure 2 offers a distinct perspective, revealing a segment of the digital twins generated from the UAV data. When scrutinized at the scale depicted in Figure 1, subtle yet discernible disparities in image quality become evident. Notably, the UAV-derived imagery exhibits a notably crisper and more vibrant appearance. This results in enhanced visual clarity, allowing for finer details to come to the forefront.

Nevertheless, it is imperative to emphasize that both depictions serve their respective purposes with excellence. They effectively convey the historical site's characteristics, offering valuable insights into its physical layout and geographical context. Whether utilizing UAV-derived or satellite imagery, users can equally benefit from these visual representations, each contributing to an enriched understanding of the site's intricacies.

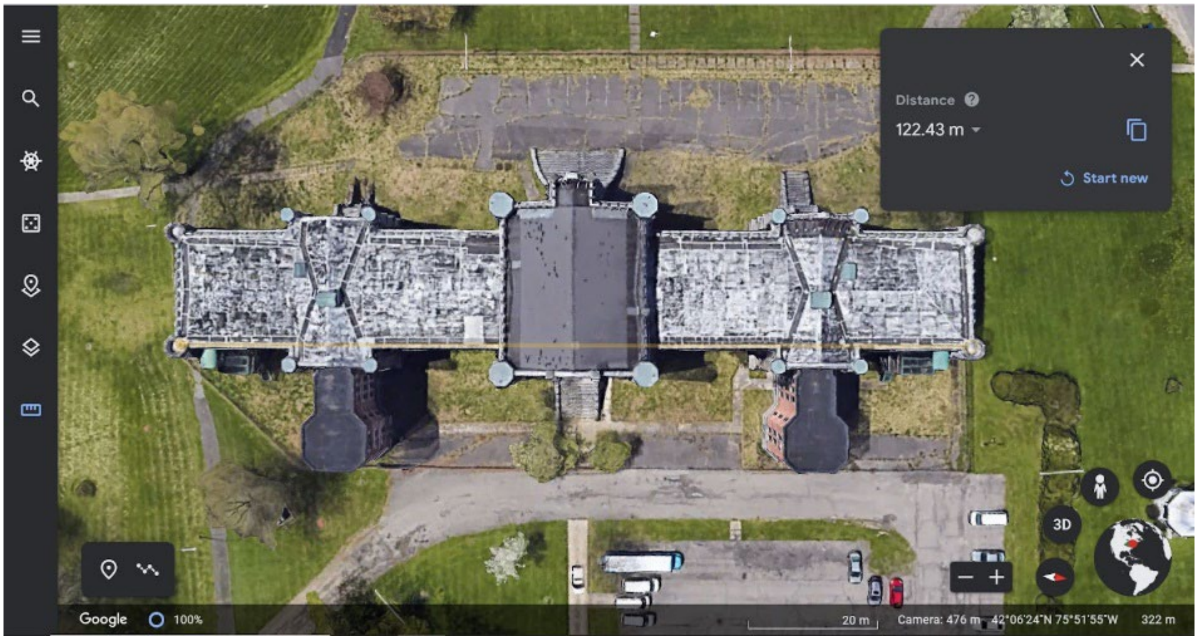

Figure 2. Image from Google Earth. (Source: Google Earth, n.d.)

Figure 3. Image from Drone 3D model.

5.2. Accuracy result

In this section, I assess the accuracy of the measurements of the New York State Inebriate Asylum building using various tools and methods, including Bentley ContextCapture Viewer, Google Earth, Google Maps, and ArcGIS. The aim is to evaluate the precision of a UAV's 3D model in determining the dimensions of the asylum building. The accuracy analysis primarily focused on detecting the accuracy of building edge lengths. The ten edge lengths of the New York State Inebriate Asylum were measured using Bentley ContextCapture Viewer and a handheld CIGMAN Laser Measurement Tool. The statistical results of the accuracy check for edge lengths using UAV, Google Earth, Google Maps, and ArcGIS are presented in Table 1.

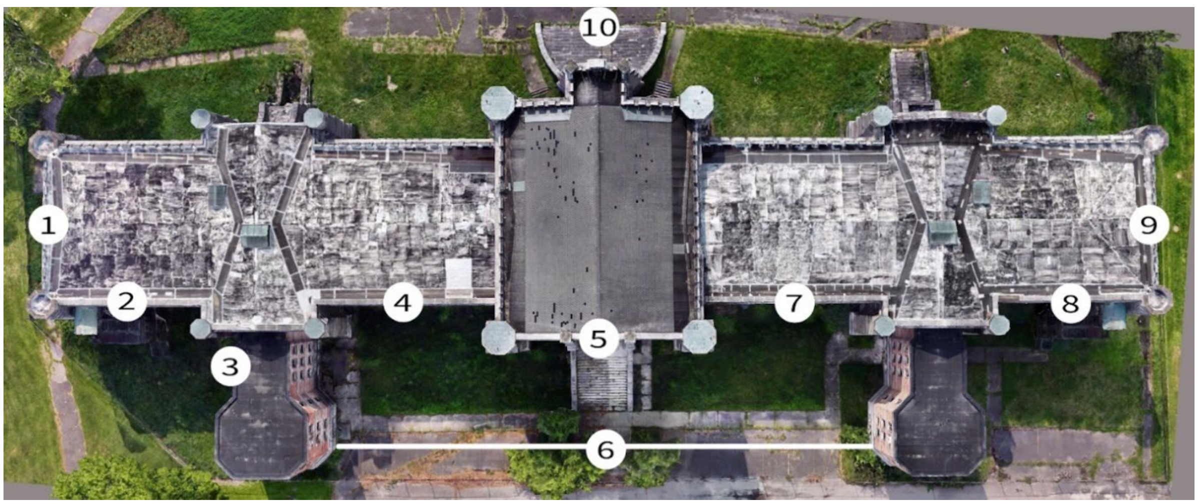

Figure 4. Building edge measurements.

Table 1. Edge Length Accuracy Check Statistics.

Actual Length	UAV			Google Earth			Google Maps			ArcGIS		
L/m	L/m	Error △ L/cm	Percent Error/ %	L/m	Error △ L/cm	Percent Error/ %	L/m	Error△ L/cm	Percent Error/ %	L/m	Error△ L/cm	Percent Error/ %
12.12	12.15	3	0.25	12.31	19	1.57	12.02	10	0.83	13.42	130	10.73
13.95	14.02	7	0.50	13.09	86	6.16	13.27	68	4.87	14.6	65	4.66
6.56	6.68	12	1.83	6.74	18	2.74	6.67	11	1.68	6.03	53	8.08

17.97	17.79	18	1.00	18.62	65	3.62	18.03	6	0.33	16.77	120	6.68
15.85	15.87	2	0.13	15.21	64	4.04	15.84	1	0.06	16.18	33	2.08
58.26	58.09	17	0.29	56.61	165	2.83	57.88	38	0.65	58.16	10	0.17
17.92	18.09	17	0.95	15.29	263	14.68	16.65	127	7.09	19.06	114	6.36
13.87	13.93	6	0.43	14.35	48	3.46	14.07	20	1.44	13.61	26	1.87
12.15	12.21	6	0.49	13.07	92	7.57	12.98	83	6.83	12.86	71	5.84
13.02	12.91	11	0.84	12.98	4	0.31	12.84	18	1.38	12.84	18	1.38

From Table 1, it can be observed that:

- The average error for UAV measurements is 9.9 cm with an average percentage error of 0.67%. This indicates that, on average, the UAV measurements were relatively close to the actual lengths, with errors typically less than 10 cm. However, there are still some discrepancies, suggesting potential limitations in precision or accuracy for certain edges.
- With an average error of 82.4 cm and an average percentage error of 4.7%, Google Earth measurements exhibit larger discrepancies compared to UAV measurements. This suggests that Google Earth may not be as precise in capturing the dimensions of the building accurately.
- Google Maps shows an average error of 38.2 cm with an average percentage error of 2.52%, indicating moderate accuracy compared to UAV and Google Earth. While still prone to discrepancies, Google Maps may offer a more reliable measurement option compared to Google Earth.

- The average error for ArcGIS measurements is 64 cm with an average percentage error of 4.79%, positioning it between Google Maps and Google Earth in terms of accuracy. ArcGIS measurements exhibit larger discrepancies compared to UAV but may still provide valuable data for planning purposes.

Overall, the measurements from the UAV appear to be relatively close to the actual lengths compared to the other tools/methods. However, there are discrepancies in some measurements across all methods, indicating potential limitations in accuracy for certain edges. For example, edge 6 shows differences of 17, 165, 38, and 10 centimeters between the actual length and the measurements from UAV, Google Earth, Google Maps, and ArcGIS, respectively. These variations suggest challenges in accurately capturing the dimensions of the building, particularly for longer edges or areas with complex geometry.

It is important to note that while UAV-derived measurements show smaller errors compared to other methods, they still exhibit discrepancies. This highlights the need for careful consideration and validation when using UAV technology for precise measurements in urban and regional planning contexts. It is also crucial to note that Google Earth's documentation acknowledges potential inaccuracies in distance measurements in areas with complex 3D terrain and buildings (Google earth help, n.d.). Given this information, the accuracy of measurements must be scrutinized.

Comparing the measurements from ArcGIS and Google Maps, there is close correspondence, with only slight variations. This suggests that both these tools provide consistent results. In contrast, Google Earth's measurements stand out different, likely due to the complex 3D terrain and building effects mentioned in its documentation.

Based on this comprehensive analysis, it becomes evident that the UAV's 3D model offers a commendable level of accuracy when measuring the dimensions of the asylum building, particularly when compared with corroborating results from ArcGIS and Google Maps. However, it is imperative to approach the utilization of Google Earth with caution, especially in areas characterized by complex terrain, as it may introduce significant discrepancies in measurements. In the field of urban planning and 3D modeling, precision is not merely desirable but indispensable. Accurate measurements serve as the bedrock upon which reliable data analysis and informed decision-making rest. They empower stakeholders to envision, plan, and execute projects with confidence, ensuring optimal resource allocation and minimal environmental impact. Therefore, the integration of precise UAV-generated 3D models with web-based platforms not only enriches the depth of available data but also strengthens the credibility and efficacy of planning endeavors. In essence, precision measurements not only enhance our understanding of the built environment but also pave the way for sustainable and resilient urban development practices that harmonize societal needs with ecological imperatives.

5.3. Comparative Evaluation

Urban and regional planning tasks benefit from various 3D models, each with its own strengths and weaknesses. Drone-generated 3D models and web-based 3D models (accessible through platforms such as Google Earth and ArcGIS OpenStreetMap) have distinct characteristics that affect their suitability for different planning scenarios. The comparative evaluation of the advantages, limitations, suitable and unsuitable scenarios for drone-generated 3D model and web-based 3D model is presented in Table 2.

Table 2: Comparative Analysis of Suitability for Drone 3D Models and Web 3D Models

Type	Advantages	Limitations	Suitable Scenarios	Unsuitable Scenarios
Drone 3D Models	1. Extremely high spatial resolution. 2. Equipped with advanced cameras, capturing images with unparalleled detail. 3. Fast and on-demand surveying, ensuring timeliness. 4. Detailed Digital Terrain Models (DTM) and Digital Surface Models (DSM) from multiple angles.	1. Limited coverage due to flight time and battery constraints. 2. Operating costs may be high, including costs related to equipment, personnel, and regulatory compliance. 3. Weather conditions can disrupt data collection, leading to delays and affecting data accuracy.	1. Tasks requiring high accuracy, such as on-site assessment of construction projects or infrastructure development. 2. Emergency response, disaster management, and real-time monitoring of construction projects. 3. Terrain modeling for tasks like flood risk assessment and geomorphological analysis.	1. Not suitable for large-scale regional planning scenarios. 2. Not suitable for scenarios with strict cost controls. 3. Not suitable for scenarios with adverse weather conditions.
Web 3D Models	1. Open to the public and planners globally, providing a comprehensive view of urban and regional environments. 2. Cost-effective, often free or available at symbolic costs. 3. Maintains consistent historical data for	1. May lack the level of detail required for precise planning tasks and may not capture fine-grained elements. 2. Updates to web-based models may have a time lag, resulting in planners using outdated information.	1. Large-scale regional planning work, such as assessing traffic networks or land use patterns across entire cities or regions. 2. Emergency response scenarios, where web-based models can provide broader background and historical data.	1. Not suitable for scenarios requiring high precision. 2. Not suitable for small-scale specific architectural planning scenarios. 3. Not suitable for scenarios requiring real-time reflection of current urban

	tracking changes over time.	3. Limited control for planners over data and models presented on web-based platforms.		development or changes.

One notable advantage of UAV-generated 3D models is their exceptionally high spatial resolution. Equipped with advanced cameras, UAVs capture imagery with unparalleled detail, making them invaluable for tasks requiring precision, such as site assessments for architectural projects or infrastructure development. Additionally, UAV surveys are rapid and can be conducted on-demand, ensuring timeliness-a crucial factor in emergency response, disaster management, and real-time monitoring of construction projects (Nex et al., 2022). Moreover, the flexibility and customization options associated with UAV missions enable planners to define flight paths, altitudes, and camera settings, ensuring data accuracy and completeness. The capability to create detailed digital terrain models (DTMs) and digital surface models (DSMs) from multiple angles enhances terrain modeling for tasks like flood risk assessment and landform analysis (Diaz et al., 2022). Finally, While UAV surveys offer the advantage of minimal intrusion, particularly in densely populated urban areas, they also raise significant privacy concerns due to their ability to capture highly detailed imagery. This requires clear guidelines and regulations to ensure compliance with privacy laws and ethical standards, including obtaining informed consent, anonymizing sensitive data, and adhering to regulatory frameworks.

Despite their advantages, UAV-generated 3D models have limitations. One significant constraint is their limited coverage area. UAVs are constrained by flight time limitations and battery capacity, making them less suitable for large-scale regional planning compared to web-based models. Additionally, operational costs can be substantial, including expenses related to equipment, personnel, and regulatory compliance, potentially rendering UAV deployments cost-prohibitive for some planning projects (Luhmann et al., 2020). Moreover, UAV operations are weather-dependent, and adverse weather conditions can disrupt data collection efforts, potentially causing delays and affecting data accuracy. Lastly, navigating regulatory restrictions and obtaining the necessary permits can be a complex process, adding administrative challenges to UAV-based data collection.

Web-based 3D models, on the other hand, offer their own set of advantages. They are globally accessible to the public and planners, providing a comprehensive view of urban and regional environments without geographical constraints. Furthermore, these models are typically cost-effective, with access often being free or available at a nominal cost. Additionally, web-based platforms often maintain consistent and historical data, allowing planners to track changes over time and assess urban development patterns. However, web-based models also may lack the level of detail required for precise planning tasks and might not capture fine-grained features or provide the necessary spatial resolution. Furthermore, updates to web-based models may have a lag time, meaning planners could be working with outdated information that does not reflect very recent developments in the urban environment. Additionally, planners have limited control over the data and models presented on web-based platforms, as customization options are often restricted.

The choice between UAV-generated 3D models and web-based 3D models in urban and regional planning depends on the specific planning task, budget, data accuracy requirements, and the need for customization or global accessibility. UAV-generated 3D models excel in site-specific planning tasks requiring high spatial resolution, such as designing a new urban park or assessing a single building's structural integrity. Conversely, web-based models are better suited for regional planning exercises that require a broad overview of a large area, such as assessing transportation networks or land-use patterns across an entire city or region. In emergency response scenarios, UAVs offer timely and precise data collection for rapid decision-making, while web-based models provide broader context and historical data. Lastly, cost-conscious projects may favor web-based models due to their cost-effectiveness, especially when the required level of detail can be met through existing web-based data sources. Effective planning often involves a combination of both methods to leverage their respective strengths and overcome their limitations.

5.4. Youth engagement benefits

Engaging youth in urban and regional planning is essential for fostering a participatory and democratic culture. By involving young people in the process of preservation and building material reuse, planners can tap into their creativity, enthusiasm, and insights while enhancing their civic awareness and skills.

One method of engaging youth is through Photovoice, where they gather photographs and videos of their community and use interview techniques to analyze their observations. This approach allows them to envision improvements and communicate their ideas effectively. Additionally, youth can explore other methods like creative media, brainstorming, and collage scenarios, which are then woven into a zine. These are methods and media that were used in the Cornell Undergrad Research to Action – Youth initiative and student organization that was incubated by researchers in the Just Places Lab.

Within the Cornell Undergrad Research to Action – Youth initiative (CURTA-Y), researchers explored methodologies like Photovoice and creative tools such as zine-making to empower young minds and amplify their voices. In this context, I provided a demonstration of drone technology for youth in Binghamton, leveraging images and 3D models of the asylum to engage co-researchers. During the session, I guided participants in understanding the intricacies of aerial photography and the techniques required to generate a 3D model of the building from multiple perspectives. Youth were given firsthand opportunities to operate the drone, experiencing firsthand the process of capturing aerial imagery. Witnessing the clarity and detail of the 3D model, they were intrigued and inspired, fostering a newfound appreciation for the potential of drones in urban planning and preservation efforts.

In subsequent sessions, youth delved into the creation of a zine depicting the historical site. Composed of real images captured by the drone, the zine serves as a tangible representation of their vision for the future of the building. As it unfolds into a model of the historic site, it unveils ideas for repurposing dismantled materials, and fostering dialogue and action among policymakers and stakeholders. Through these innovative approaches, CURTA-Y not only empowers youth to articulate their ideas and aspirations but also fosters a deeper understanding of community engagement and urban planning processes. It was therefore found that drone 3D models can be utilized to offer immersive visualizations of the urban environment and potential changes. These models spark interest and curiosity among youth, allowing them to explore different scenarios and options. Unlike professional planners, youth are likely to view drones as tools rather than intrusive devices, fostering a positive attitude towards their use. Drone 3D models also serve as a platform for dialogue and collaboration among youth, planners, policymakers, and community members. Through these models, youth can share their opinions and visions, while learning from others' perspectives and experiences. By involving young people in shaping public policy and decision-making processes related to preservation and building material reuse, planners can empower the younger generation and create a more sustainable and inclusive urban future.

In gathering ideas for engaging future cohorts of high school co-researchers, it is crucial to encourage them to dream up new futures for old buildings and turn research into action. By integrating drone photography into our experimentation with Photovoice and zine-making, the project aims to cultivate a new generation of urban planners and leaders who are equipped to drive positive change in their communities.

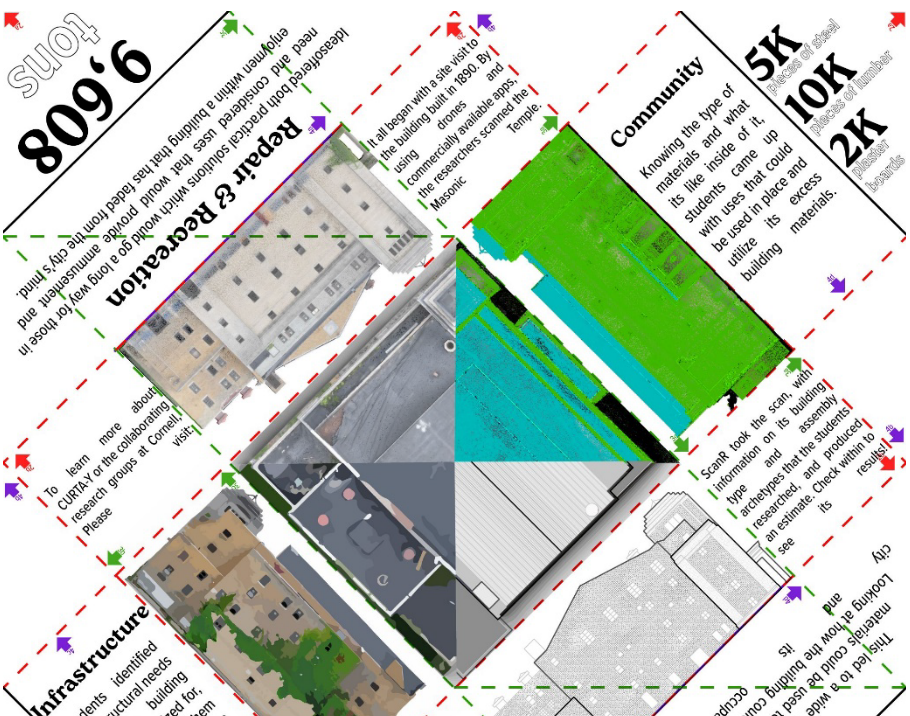

Figure 5. Zine creation from CURTA-Y.

5.5. The path forward

The fusion of UAV-generated 3D models and web-based 3D models presents a potent opportunity to elevate public engagement and decision-making processes in urban and regional planning. By harnessing the complementary strengths of these models, urban planners, policymakers, and researchers can create more comprehensive and accessible tools, fostering greater public involvement and informed decision-making.

One of the primary advantages of this fusion lies in its capacity to offer interactive visualizations. By combining UAV-generated and web-based 3D models, planners can craft immersive experiences that enable the public to explore urban environments from multiple angles. This interactive engagement can make urban planning discussions more accessible and transparent, drawing citizens into the decision-making process. This fusion facilitates virtual public consultations, a powerful tool in urban planning. Stakeholders can virtually navigate proposed developments, provide feedback, and participate in planning discussions from remote locations. This approach democratizes the process, broadening participation and making decision-making more inclusive.

Additionally, these fused models can serve educational purposes, as described in the case study of CURTA-Y above, aiding schools and community organizations in teaching urban planning concepts. By offering engaging tools for learning about the built environment, this approach not only enhances public awareness but also nurtures a deeper sense of awareness and enhances ownership and connection among residents.

In terms of decision-making, the fusion of models provides invaluable support. Decision-makers can access a wealth of data derived from UAV surveys and web-based sources to inform their choices. This data-driven decision support facilitates evidence-based planning, enhancing the effectiveness of decisions related to land use, infrastructure development, and disaster preparedness.

Moreover, the fused models enable decision-makers to visualize different planning scenarios and their potential impacts on the urban environment. This aids in evaluating alternatives and selecting the most suitable courses of action, enhancing the quality of decisions. The fusion of models also aids in risk assessment. Decision-makers can use these models to visualize risks, such as flood hazards, in three dimensions. This empowers them to allocate resources for mitigation and preparedness effectively, reducing vulnerabilities and enhancing urban resilience. To maximize the benefits of this fusion, researchers must pay careful attention to model quality. Integration of various data sources, including ground surveys, aerial imagery, and geospatial data, is crucial. This comprehensive approach ensures that the fused models are accurate and up to date, providing reliable foundations for planning and decision-making.

Rigorous model validation processes, including ground truthing and accuracy assessments, are essential for enhancing model quality. Researchers should validate the fused models against ground data to ensure their reliability for planning and decision-making. In addition, researchers should establish protocols for keeping the fused models current, reflecting changes in the urban environment accurately. This ensures that decision-makers always have access to the most up-to-date and relevant data.

Integrating landscape or land surveying into the fusion of UAV-generated 3D models and web-based 3D models presents both opportunities and challenges in urban and regional planning. While these models excel at capturing built environments and infrastructure, they may encounter difficulties in accurately representing natural features such as trees, lakes, and terrain variations (Lu, 2019). 3D modeling software often struggles with accurately depicting natural elements. Trees, for example, pose challenges due to their height and susceptibility to wind, leading to potential issues with overlap and consistency in modeling. Similarly, water features like lakes present difficulties as there are no consistent features to use as tie points. Incorporating landscape surveying into the fusion of 3D models opens avenues for measuring and predicting landscape changes over time (Luo et al., 2022). By monitoring factors such as vegetation growth, erosion, and land use patterns, planners can better anticipate environmental impacts and incorporate sustainability measures into urban planning initiatives.

In summary, the fusion of UAV-generated 3D models and web-based 3D models holds immense potential for enhancing public engagement and decision-making in urban and regional planning. Its benefits encompass interactive visualization, virtual consultations, educational opportunities, data-driven decision support, scenario visualization, and risk assessment. To enhance the quality of these models, researchers must focus on data integration, advanced analytics, validation processes, and regular updates, ensuring that the models remain accurate and reliable tools for planning and decision-making.

CONCLUSION AND FUTURE PROSPECTS

In conclusion, the use of unmanned aerial vehicles (UAVs) for photogrammetry and 3D modeling is a promising method for data collection in urban areas. Compared with traditional methods such as airplane or helicopter images, UAVs offer many advantages such as the ability to mount different cameras, operate in areas that may be off limits to larger aircraft, and create higher-resolution images. The resulting 3D models can be used for various purposes such as improving maintenance or assisting in planning projects, as well as contributing to the historic preservation efforts.

The case study discussed here exemplifies the transformative potential of UAV 3D modeling, particularly in medium-scale mapping projects such as the detailed reconstruction of the New York State Inebriate Asylum. This demonstration underscores the broader significance of integrating UAV technology into heritage preservation and urban planning initiatives. Furthermore, it highlights the crucial role of youth engagement in fostering participatory practices within these fields. By leveraging UAV-generated 3D models as educational tools, immersive learning experiences can be crafted, sparking curiosity and interest among young learners. This engagement not only nurtures a deeper understanding of planning, architecture, and preservation but also instills a sense of responsibility and ownership among the younger generation, thus contributing to the creation of a more sustainable and equitable urban future.

Moreover, the potential applications of UAV 3D modeling in historic preservation extend beyond mere documentation. Through the surveying and mapping of historical landmarks and structures, UAVs provide invaluable insights to urban planners and heritage organizations. These insights guide preservation efforts, ensuring the safeguarding of a city's cultural heritage for future generations. Integration of these 3D models into gaming and rendering software further enhances their utility, allowing for the creation of immersive virtual reality experiences. These experiences not only serve as educational tools but also offer opportunities for interactive exploration, deepening participants' understanding of the cultural significance of historical sites. Additionally, the use of UAV 3D models in gaming and rendering software can assist planners in envisioning adaptive reuse strategies for historical structures within contemporary urban contexts.

Looking ahead, the prospects for UAVs in photogrammetry and 3D modeling are promising. Incorporating diverse perspectives from technologies such as infrared cameras, 360° cameras, and LiDAR can significantly enhance the accuracy and versatility of models. For example, integrating infrared cameras into UAV photogrammetry and 3D modeling enables the detection of energy leaks in buildings, facilitating more efficient repairs and energy conservation efforts, thus enhancing sustainability. Furthermore, 360° cameras have the potential to streamline data acquisition processes and even allow for interior modeling of structures. LiDAR technology, particularly showcased in CURTA-Y's demonstration with phones to estimate materials, illustrates innovative applications of UAV-based photogrammetry and 3D modeling in urban planning and heritage preservation projects. As the surveying and urban planning community embraces these new technologies, UAVs' integration into standard procedures will redefine the landscape of urban space analysis and development. UAV mapping for photogrammetry and 3D modeling in urban spaces will likely become increasingly prevalent, reflecting a shift towards more advanced and efficient methodologies within the sector.

BIBLIOGRAPHY

Alsadik, B., & Khalaf, Y. H. (2022). Potential use of drone ultra-high-definition videos for detailed 3d city modeling. ISPRS International Journal of Geo-Information, 11(1), 34. https://doi.org/10.3390/ijgi11010034

Banfi, F., Roascio, S., Mandelli, A., & Stanga, C. (2023). Narrating ancient roman heritage through drawings and digital architectural representation: From historical archives, uav and lidar to virtual-visual storytelling and hbim projects. Drones, 7(1), 51. https://doi.org/10.3390/drones7010051

Barba, S., Barbarella, M., Di Benedetto, A., Fiani, M., Gujski, L., & Limongiello, M. (2019). Accuracy assessment of 3d photogrammetric models from an unmanned aerial vehicle. Drones, 3(4), 79. https://doi.org/10.3390/drones3040079

Cheng, M.-L., Matsuoka, M., Liu, W., & Yamazaki, F. (2022). Near-real-time gradually expanding 3D land surface reconstruction in disaster areas by sequential drone imagery. Automation in Construction, 135, 104105. https://doi.org/10.1016/j.autcon.2021.104105

Diaz, N. D., Highfield, W. E., Brody, S. D., & Fortenberry, B. R. (2022). Deriving first floor elevations within residential communities located in galveston using uas based data. Drones, 6(4), 81. https://doi.org/10.3390/drones6040081

Fytsilis, A. L., Prokos, A., Koutroumbas, K. D., Michail, D., & Kontoes, C. C. (2016). A methodology for near real-time change detection between Unmanned Aerial Vehicle and wide area satellite images. ISPRS Journal of Photogrammetry and Remote Sensing, 119, 165–186. https://doi.org/10.1016/j.isprsjprs.2016.06.001

Google Earth (n.d.). Retrieved March 11, 2024, from https://earth.google.com/web/@42.10656318,-75.86566223,344.7279694a,214.75902333d,35y,-159.75252881h,26.08213289t,0r/data=OgMKATA

Grubesic, T. H., Wallace, D., Chamberlain, A. W., & Nelson, J. R. (2018). Using unmanned aerial systems (UAS) for remotely sensing physical disorder in neighborhoods. Landscape and Urban Planning, 169, 148-159. https://doi.org/10.1016/j.landurbplan.2017.09.001

Hu, D., & Minner, J. (2023). Uavs and 3d city modeling to aid urban planning and historic preservation: A systematic review. Remote Sensing, 15(23), 5507. https://doi.org/10.3390/rs15235507

Kaimaris, D., Georgoula, O., Patias, P., & Stylianidis, E. (2011). Comparative analysis on the archaeological content of imagery from Google Earth. Journal of Cultural Heritage, 12(3), 263–269. https://doi.org/10.1016/j.culher.2010.12.007

Kleinschroth, F., Banda, K., Zimba, H., Dondeyne, S., Nyambe, I., Spratley, S., & Winton, R. S. (2022). Drone imagery to create a common understanding of landscapes. Landscape and Urban Planning, 228, 104571. https://doi.org/10.1016/j.landurbplan.2022.104571

Koc, A. B., Anderson, P. T., Chastain, J. P., & Post, C. (2020). Estimating rooftop areas of poultry houses using uav and satellite images. Drones, 4(4), 76. https://doi.org/10.3390/drones4040076

Liang, H., Li, W., Zhang, Q., Zhu, W., Chen, D., Liu, J., & Shu, T. (2017). Using unmanned aerial vehicle data to assess the three-dimension green quantity of urban green space: A case study in Shanghai, China. Landscape and Urban Planning, 164, 81-90. https://doi.org/10.1016/j.landurbplan.2017.04.006

Liénard, J., Vogs, A., Gatziolis, D., & Strigul, N. (2016). Embedded, real-time UAV control for improved, image-based 3D scene reconstruction. Measurement, 81, 264–269. https://doi.org/10.1016/j.measurement.2015.12.014

Lu, Y. (2019). Using Google Street View to investigate the association between street greenery and physical activity. Landscape and Urban Planning, 191, 103435. https://doi.org/10.1016/j.landurbplan.2018.08.029

Luhmann, T., Chizhova, M., & Gorkovchuk, D. (2020). Fusion of uav and terrestrial photogrammetry with laser scanning for 3d reconstruction of historic churches in georgia. Drones, 4(3), 53. https://doi.org/10.3390/drones4030053

Luo, J., Zhao, T., Cao, L., & Biljecki, F. (2022). Semantic Riverscapes: Perception and evaluation of linear landscapes from oblique imagery using computer vision. Landscape and Urban Planning, 228, 104569. https://doi.org/10.1016/j.landurbplan.2022.104569

Measure distances and areas in google earth—Computer—Google earth help. (n.d.). Retrieved from https://support.google.com/earth/answer/9010337?hl=en&co=GENIE.Platform%3DDesktop

Nagasawa, R., Mas, E., Moya, L., & Koshimura, S. (2021). Model-based analysis of multi-UAV path planning for surveying postdisaster building damage. Scientific Reports, 11(1), 18588. https://doi.org/10.1038/s41598-021-97804-4

New york state inebriate asylum(U. S. National park service). (n.d.). Retrieved from https://www.nps.gov/places/new-york-state-inebriate-asylum.htm

Nex, F., Armenakis, C., Cramer, M., Cucci, D. A., Gerke, M., Honkavaara, E., Kukko, A., Persello, C., & Skaloud, J. (2022). UAV in the advent of the twenties: Where we stand and what is next. ISPRS Journal of Photogrammetry and Remote Sensing, 184, 215–242. https://doi.org/10.1016/j.isprsjprs.2021.12.006

Parikh, T., Egendorf, S. P., Murray, I., Jamali, A., Yee, B., Lin, S., Cooper-Smith, K., Parker, B., Smiley, K., & Kao-Kniffin, J. (2022). Greening the virtual smart city: Accelerating peer-to-peer learning in urban agriculture with virtual reality environments. Frontiers in Sustainable Cities, 3. https://www.frontiersin.org/articles/10.3389/frsc.2021.815937

Park, K., & Ewing, R. (2017). The usability of unmanned aerial vehicles (UAVs) for measuring park-based physical activity. Landscape and Urban Planning, 167, 157-164. https://doi.org/10.1016/j.landurbplan.2017.06.010

Qin, R., Gruen, A., & Huang, X. (2012, November). UAV project-building a reality-based 3D model of the NUS (National University of Singapore) campus. In Proceeding of the 33rd Asian Conference on Remote Sensing (pp. 26-30).

Satish, S. (2021, September 15). Satellite vs drone imagery: Knowing the difference and effectiveness of supervision earth’s…. Supervisionearth. https://medium.com/supervisionearth/satellite-vs-drone-imagery-knowing-the-difference-and-effectiveness-of-supervision-earths-90e98b78777c

Sestras, P., Roșca, S., Bilașco, Ștefan, Naș, S., Buru, S. M., Kovacs, L., Spalević, V., & Sestras, A. F. (2020). Feasibility assessments using unmanned aerial vehicle technology in heritage buildings: Rehabilitation-restoration, spatial analysis and tourism potential analysis. Sensors (Basel, Switzerland), 20(7), 2054. https://doi.org/10.3390/s20072054

Siebert, S., & Teizer, J. (2014). Mobile 3D mapping for surveying earthwork projects using an Unmanned Aerial Vehicle (Uav) system. Automation in Construction, 41, 1–14. https://doi.org/10.1016/j.autcon.2014.01.004

Skondras, A., Karachaliou, E., Tavantzis, I., Tokas, N., Valari, E., Skalidi, I., Bouvet, G. A., & Stylianidis, E. (2022). Uav mapping and 3d modeling as a tool for promotion and management of the urban space. Drones, 6(5), 115. https://doi.org/10.3390/drones6050115

Tan, Y., & Li, Y. (2019). Uav photogrammetry-based 3d road distress detection. ISPRS International Journal of Geo-Information, 8(9), 409. https://doi.org/10.3390/ijgi8090409

Watts, A. C., Ambrosia, V. G., & Hinkley, E. A. (2012). Unmanned aircraft systems in remote sensing and scientific research: Classification and considerations of use. Remote Sensing, 4(6), 1671–1692. https://doi.org/10.3390/rs4061671

Xu, Z., Wu, L., Gerke, M., Wang, R., & Yang, H. (2016). Skeletal camera network embedded structure-from-motion for 3D scene reconstruction from UAV images. ISPRS Journal of Photogrammetry and Remote Sensing, 121, 113–127. https://doi.org/10.1016/j.isprsjprs.2016.08.013

Zhao, S., Kang, F., Li, J., & Ma, C. (2021). Structural health monitoring and inspection of dams based on UAV photogrammetry with image 3D reconstruction. Automation in Construction, 130, 103832. https://doi.org/10.1016/j.autcon.2021.103832

Zhou, L., Meng, R., Tan, Y., Lv, Z., Zhao, Y., Xu, B., & Zhao, F. (2022). Comparison of UAV-based LiDAR and digital aerial photogrammetry for measuring crown-level canopy height in the urban environment. Urban Forestry & Urban Greening, 69, 127489. https://doi.org/10.1016/j.ufug.2022.127489

Zulkifli, M. H., & Tahar, K. N. (2023). The influence of uav altitudes and flight techniques in 3d reconstruction mapping. Drones, 7(4), 227. https://doi.org/10.3390/drones7040227