COMP6002 Computer Science Project Proposal

From 2D to 3D:
Innovative Digital Reconstruction
in Civil Infrastructure

Group 14

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1. Introduction

1.1 Background

3D reconstruction is a technical process of building three-dimensional digital models of real objects or scenes, typically referring to the generation of 3D models from 3D images('3D Reconstruction' 2023; '3-D Reconstruction - Latest Research and News | Nature', n.d.-a). The 3D models created by 3D reconstruction are mathematical representations suitable for computer processing and manipulation. The entire process of generating a 3D model involves many steps, including image acquisition, camera calibration, feature extraction, stereo correspondence, and restoration('3D Reconstruction' 2023). There are four conventional data formats for representing 3D reconstruction models: depth map, point cloud, voxel, and mesh(Xu, Tong, and Stilla 2021). Among these, the point cloud is a collection of data points representing the exterior surface of a 3D object or scene(Remondino 2003). Relative to other forms of representation, it offers greater directness and simplicity, as well as being easier to acquire and process, with strong flexibility. Therefore, the point cloud is the most fundamental form of expression in 3D reconstruction(Z. Ma and Liu 2018) and has a wide range of applications(W. Liu et al. 2019).

The current application areas of 3D reconstruction technology are very diverse, including terrain mapping(Feng and Atanasov 2021) which captures the precise elevation details of real terrains for 3D reconstruction, used in terrain analysis and urban planning; industrial design(Haibo 2017) which scans existing physical objects to generate 3D data for design and improvement of industrial products; medical imaging(Abreu de Souza et al. 2023) which involves precise measurement or 3D reconstruction of body parts, used for surgical planning and the design of custom medical devices for patients; as well as movies and video games(S. Liu, Nie, and Hamid 2022; Bebie and Bieri 2000) which create realistic 3D models and backgrounds by scanning real objects and scenes, enhancing the authenticity of visual effects.

In the field of civil infrastructure, 3D reconstruction technology also has a variety of applications, holding significant long-term implications for the whole lifecycle (including stages such as planning, design, production, construction, operation, renovation, and demolition, etc.) of infrastructure(Fathi, Dai, and Lourakis 2015). 3D reconstruction technology enables engineers and planners to design and plan infrastructure with unprecedented precision and detail. Utilizing virtual 3D models corresponding to the real world allows for more accurate assessments of design proposals, optimization of structural layouts, and the reduction of potential design errors, thereby saving labour costs and time(Y. Wang, (John) Zhai, and Xue 2022). The models created by 3D reconstruction can be used for pre-construction simulation and planning, assisting construction teams in understanding complex design features and detecting and solving potential construction issues in advance(Jiang et al. 2020). Furthermore, 3D reconstruction can rapidly construct digital representations of construction sites, allowing managers to monitor progress remotely(Xue, Hou, and Zeng 2021). It can also be combined with Building Information Modeling (BIM) technology to further improve the efficiency and accuracy of the construction process(Lu and Lee 2017). 3D reconstruction technology can provide detailed 3D digital replicas of infrastructure, which is critical for the daily management and maintenance of facilities. Managers can use these 3D models to carry out activities such as facility condition monitoring, performance evaluation, and maintenance(Lu and Lee 2017). Technicians can remotely detect equipment and facilities in high-risk environments, effectively improving the operational efficiency and safety of the equipment(J. Wang et al. 2023). For historic buildings and cultural heritage, 3D reconstruction offers a way to protect and document these priceless treasures. By creating accurate 3D models, these buildings can be analyzed in detail, restoration options can be designed, and even historic buildings can be reconstructed where the original structure has been damaged or lost (Ragia, Sarri, and Mania 2015; Gregor et al. 2014). After natural disasters (such as earthquakes, floods, and typhoons) occur, 3D reconstruction technology can quickly provide detailed views of damaged areas, help assess the extent of damage, guide emergency response and reconstruction work, and effectively reduce the impact of disasters(Yamazaki et al. 2017).

It can be seen that 3D reconstruction technology can significantly improve various aspects of civil infrastructure such as design, construction, management and protection efficiency, and is one of the indispensable technologies for the development of modern cities and society. However, the application of 3D reconstruction technology in the civil engineering field is still in its infancy (Ma and Liu 2018) and has not fully met the requirements in terms of accuracy, operation time, and automation. Therefore, there is an urgent need to conduct more research to meet the needs of civil infrastructure various potential and valuable applications.

1.2 Motivation

The motivation of this research includes three aspects. The first is the current status of 3D reconstruction technology itself, the second is the application of 3D reconstruction technology in the field of civil infrastructure, and the third is my background.

（1）Current status of 3D reconstruction technology

With the rapid growth of computing power and the continuous advancement of image processing technology, 3D reconstruction technology has achieved significant development. These technologies not only provide richer and more accurate spatial information than traditional 2D images, but also open up new research and application areas. Despite this, 3D reconstruction technology, which is a core technology in many fields such as computer graphics, computer vision, and virtual reality(‘3D Reconstruction’ 2023), is still difficult to handle in terms of processing complex scenes(Kang et al. 2020), modelling accuracy(C. Liu et al. 2021), improving reconstruction speed, being difficult to use in real-time (Cheng et al. 2022), reducing operation time(Z. Ma and Liu 2018), and reducing costs(Khilar, Chitrakala, and SelvamParvathy 2013). It is faced with daunting challenges. Therefore, exploring innovative 3D reconstruction methods to adapt to changing application requirements has become one of the important motivations for this research.

（2）Application of 3D reconstruction technology in civil infrastructure

In the field of civil infrastructure, the application of 3D reconstruction technology has demonstrated its great potential for improving engineering design accuracy(Y. Wang, (John) Zhai, and Xue 2022)., promoting construction management efficiency(Xue, Hou, and Zeng 2021), and enhancing cultural heritage protection(Ragia, Sarri, and Mania 2015; Gregor et al. 2014). Especially when planning new infrastructure(Poullis and You 2011), monitoring and maintaining existing facilities(Lu and Lee 2017), and responding to emergencies(J. Wang et al. 2023), 3D reconstruction offers unparalleled advantages. However, how to effectively integrate the latest 3D reconstruction technology into the whole life cycle management of civil infrastructure is still a problem to be solved(Z. Ma and Liu 2018). The potential and challenges in this field prompt all relevant researchers to explore how to bring revolutionary changes to the civil infrastructure field through innovative digital reconstruction methods.

（3）Personal background

As a researcher with a dual background in computing and civil engineering, my unique educational and practical experience puts me in an ideal position to explore the application of 3D reconstruction technology in civil infrastructure. My computing background provides me with a technical foundation including programming, algorithm design, data processing, and image analysis capabilities, while my civil engineering background provides me with a deep understanding of the complexities and challenges involved in the design, construction, and maintenance of infrastructure. This cross-disciplinary expertise, combined with my previous experience working in smart buildings, enables me to accurately identify and solve practical application problems of 3D reconstruction technology in infrastructure management, and I am fully aware that the development of 3D reconstruction technology is the cornerstone of digital twin technology and digital twin cities.

Based on the above three aspects, I have been inspired to combine advanced technology with engineering practice to solve real-world problems in innovative ways. Through this research, I hope to consolidate the bridge between computer and civil engineering disciplines and strive to promote the integrated development of the two fields.

2. Literature Review

Looking back at the 3D reconstruction technology so far, the methods of obtaining 3D models are mainly divided into two categories(‘3D Reconstruction’ 2023). 1) Use 3D scanning equipment to actively send signals to objects or scenes to obtain information and reconstruct their 3D models. This is an active method. Such methods include laser scanning, structured light scanning, time-of-flight, consumer-grade RGB-D photography, etc. These methods are generally based on 3D reconstruction of the point cloud. Laser scanning uses a scanner to emit a laser beam onto a target object and measure the time or phase change of the laser beam reflected from the object's surface to determine the position of the object's surface(Fischer and Manor 1999),. Structured light scanning infers the 3D shape of an object's surface by projecting a series of known patterns of light, such as stripes or grids, onto the surface and observing how these patterns are distorted(Zhang 2018). Time-of-flight calculates the distance by sending a beam of light (usually infrared light) and measuring the time it takes for the light to travel from the camera to be reflected back to the camera by an object(Heide et al. 2014). Consumer RGB-D cameras work by simultaneously capturing a standard red, green, and blue (RGB) image and depth information (D stands for depth) for each pixel, where the depth information is emitted by the camera to a specific type of light (such as infrared light).), and is measured based on the interaction of light with the object surface (such as the time or pattern change of reflection)(Zollhöfer et al. 2018). Currently, RGB-D cameras include Kinect Fusion, Dynamic Fusion, Elastic Fusion, Fusion 4D, Volume and other algorithms. 2) Image-based 3D reconstruction uses computer vision theory to perform 3D modelling through multiple images taken at different angles(Han, Laga, and Bennamoun 2021). This type of method is a passive method, and it further includes two mainstream technologies, namely 3D reconstruction based on multi-view geometry and 3D reconstruction based on deep learning. For 3D reconstruction based on multi-view geometry, this 3D reconstruction method has been studied for a long time and the technology is relatively mature. It mainly estimates the camera pose of the collected data through multi-view images, and then extracts features from the images and performs comparison and splicing to complete the conversion of 2D images into 3D models(Shang et al. 2020). This technology commonly includes Structure from Motion(SfM) and Multi-View Stereo(MVS) method, etc.(D. Ma et al. 2023). For 3D reconstruction based on deep learning, this method mainly uses the super powerful learning and fitting capabilities of deep neural networks, which can perform 3D reconstruction of RGB or RGBD images(Han, Laga, and Bennamoun 2021). At the same time, this method covers a variety of data representation methods, including point cloud, mesh, and voxel, and it uses depth information and other forms of input data to generate or optimize 3D models(Han, Laga, and Bennamoun 2021). This method is mostly a supervised learning method and is highly dependent on data sets. Due to the collection and labelling problems of data sets, currently there is more research in the direction of reconstruction of smaller objects.

Of course, these 3D reconstruction methods have their advantages and challenges, and they also play a role in different application requirements. Active 3D reconstruction methods, due to their high accuracy and strong environmental adaptability, are widely used in many scenarios that require precise measurement, and the field of civil infrastructure is no exception, such as 3D reconstruction of existing buildings and construction site management(Z. Ma and Liu 2018). However, the application of this technology often requires expensive equipment and sensors(Paoli et al. 2020). Moreover, in outdoor or strong light environments, interference from external light sources such as the sun may affect the accuracy of measurements(Kang et al. 2020). In the passive 3D reconstruction method, 3D reconstruction based on multi-view geometry can reconstruct 3D models from a few to thousands of pictures as needed. It is highly adaptable and interpretable, and does not rely on previous training data. It can be directly applied to new image sets, and provides a cost-effective solution for 3D reconstruction(Shang et al. 2020). To build a model with higher accuracy, it often requires two very tedious steps: camera pose evaluation and pixel triangulation in 3D space(S. Wang et al. 2023). If the region has poor texture or is occluded, accurately matching feature points may be time-consuming and relatively difficult, affecting the quality of reconstruction and requiring deep expertise to adjust parameters and solve problems during the reconstruction process(Li et al. 2022). Although 3D reconstruction based on deep learning has large data requirements, limited generalization ability, and poor interpretability, it can fully learn complex image features and help improve the reconstruction effect in texture-poor or visually blurry areas. Besides, the degree of automation and modelling efficiency is relatively high(Han, Laga, and Bennamoun 2021).

Under this current situation, DUSt3R(S. Wang et al. 2023), a new 3D reconstruction method, provides a promising solution. DUSt3R is a point cloud-based deep learning reconstruction method that discards two key steps in the traditional 3D reconstruction process, namely camera pose evaluation and triangulation of corresponding pixels in 3D space. Making the conversion from 2D images to 3D models more convenient and faster. DUSt3R only needs to use any image set to perform 3D reconstruction, which greatly reduces the difficulty and complexity of data collection and also shortens the time to generate a 3D model.

However, although DUSt3R shows significant advantages in simplifying the reconstruction process and improving efficiency, there are still some limitations when it is applied to the 3D reconstruction of civil infrastructure (these findings are based on extensive testing and validation conducted personally by our research team). Especially when reconstructing complex infrastructure 3D scenes, its accuracy and efficiency need to be improved. This is particularly important because civil infrastructures sometimes are not only large in scale but also structurally complex, which places strict requirements on the accuracy and reliability of 3D models.

Therefore, the development and optimization of new 3D reconstruction technology, especially for applications in the field of civil infrastructure, is not only a manifestation of technological progress, but also an inevitable choice to meet social and economic needs.

3. Problem Statement

According to the challenges and limitations faced by 3D reconstruction technology above, an optimization algorithm based on a new point cloud-based deep learning 3D reconstruction method——DUSt3R is proposed, which has the potential to fill some gaps in current 3D reconstruction technology and its application in the field of civil infrastructure.

This study aims to apply an optimized 3D reconstruction method based on DUSt3R to civil infrastructure, hoping to improve its reconstruction accuracy and efficiency in complex scenes.

3.1 Research Question

The main research questions include:

- Evaluate the effectiveness of the DUSt3R method in processing different types of infrastructure data, including its accuracy, efficiency, etc.
- Discover the specific flaws and shortcomings of the DUSt3R method in the application of civil infrastructure reconstruction.
- Based on the discovered flaws and shortcomings, propose and implement algorithmic optimizations to improve the DUSt3R method.

3.2 Research Objective

The research objectives of this study are as follows:

- **Applying the DUST3R method to civil infrastructure:** Explore and implement the application of DUST3R technology in various infrastructure reconstruction projects, especially in complex scenes that are difficult to handle with traditional 3D reconstruction methods.

- **Evaluate and improve the performance of the DUSt3R method:** Through detailed experiments and analysis, evaluate the reconstruction accuracy and efficiency of DUSt3R technology in practical applications, and identify existing limitations and problems.
- **Develop targeted improvement strategies:** Based on the evaluation results, develop targeted algorithm optimization and technical improvement measures to improve the reconstruction accuracy and processing efficiency of the DUSt3R method in complex environments.
- **Applying the optimized DUSt3R to civil infrastructure:** After achieving targeted algorithm optimization and technical improvements, the improved DUSt3R method was re-applied to civil infrastructure 3D reconstruction.
- **Comparative analysis to evaluate the performance improvement of the optimization algorithm:** Through comparative analysis with the performance of the original DUST3R method, a detailed evaluation of the improvement of the optimization algorithm in terms of reconstruction accuracy, processing efficiency, and ability to cope with complex scenes is conducted to verify the effectiveness of the optimization measures and demonstrate the potential and value of DUSt3R technology in the field of civil infrastructure.

3.3 Research Scope

The research scope will focus on the following aspects:

- Conduct preliminary 3D reconstructions of selected civil infrastructure using the DUSt3R method to identify existing limitations of the method.
- Through theoretical analysis and experimental verification, develop algorithm optimization solutions to improve the conversion accuracy and processing efficiency from 2D to 3D.
- Apply the optimized DUSt3R method to different infrastructure reconstructions and evaluate its performance in practical applications, especially in terms of accuracy, efficiency, etc.
- Demonstrate the improvements and advantages of the optimized DUSt3R method through comparative analysis with existing technologies.

This research is expected to provide more efficient and accurate 3D reconstruction solutions for the field of civil infrastructure and promote the design, construction and maintenance of infrastructure in a new digital era.

4. Approach

This research will evaluate the performance of the DUSt3R 3D reconstruction method through quantitative analysis to discover the specific flaws and shortcomings of the method. Then based on these findings, an algorithmically feasible optimization method is proposed and implemented, and finally the 3D reconstruction optimization algorithm is applied to civil infrastructure.

4.1 Research Framework

The research will adopt a multi-stage research framework aimed at comprehensively evaluating, optimizing, and validating the application of the DUSt3R method in 3D reconstruction of civil infrastructure. Specific steps include:

(1) Data collection: Select multiple representative civil infrastructures as research objects, collect their point cloud data of laser scanning, and collect necessary 2D image data (such as camera shots, drone shots, public databases, public network pictures, etc.). This will include different types of infrastructure and scenes of varying complexity to ensure comprehensive assessment and optimization.

(2) 3D reconstruction: For selected civil infrastructure, the 3D reconstruction method of laser scanning is first used to record the accuracy and efficiency of the reconstruction process as baseline performance indicators (ground truth). Then use the original DUSt3R method to perform preliminary 3D reconstruction of the collected corresponding image data, and record the accuracy and efficiency of the reconstruction process. Finally, the optimized DUSt3R method is used to perform 3D reconstruction of the collected corresponding image data again, and the accuracy and efficiency of the reconstruction process are recorded.

(3) Performance evaluation: Conduct a detailed analysis of the results of the preliminary 3D reconstruction, and identify flaws and shortcomings of the original DUSt3R method in processing specific types of infrastructure data based on ground truth. The results of the final 3D reconstruction are analyzed in detail, and the advantages of applying the optimized DUSt3R method are evaluated based on ground truth and the original DUSt3R method.

4.2 Optimization of DUSt3R Method

In view of the shortcomings of the DUSt3R method and the characteristics and needs of civil infrastructure, an improvement and optimization strategy for the DUSt3R method is proposed.

Based on the results of preliminary 3D reconstruction and its performance evaluation, this research will carry out the following possible optimization work:

(1) Algorithm improvement: Design and implement algorithm improvements based on the identified performance bottlenecks and deficiencies. This may include integrating other algorithms, improving feature point detection and matching algorithms, optimizing image preprocessing processes, introducing more efficient 3D model generation strategies, etc.

(2) Specific scenario optimization: Develop specialized processing strategies and technologies for the reconstruction challenges of civil infrastructure. For example, strengthen pre-training for civil infrastructure images; explore adaptable image analysis technology for scenes with sparse textures or large illumination changes, etc.

4.3 Validation and Testing

The optimized DUSt3R method will be verified and tested in the following ways:

(1) Performance evaluation indicators: Define a comprehensive set of performance evaluation indicators, including but not limited to reconstruction accuracy, processing time, resource consumption, etc. These indicators will be used to quantify the performance difference of the DUSt3R method before and after the improvement.

Comparative analysis: Based on the performance indicators of ground truth, the performance of the optimized DUSt3R method is compared with the original DUSt3R method, and also with other existing 3D reconstruction technologies (such as Gaussian sputtering, NeRF, etc.) to highlight the advantages and improvements of the DUSt3R method.

Extended application: Apply the optimized DUSt3R method to more 3D reconstructions of civil infrastructure of different types and complexity, and evaluate its performance indicators.

5. Risk Assessment

5.1 Technology Risk

Difficulty in data collection: Obtaining high-quality, applicable 2D images may be difficult under certain types of infrastructure or complex scenarios.

Algorithm optimization does not meet expectations: Optimization of the DUST3R method may not significantly improve reconstruction accuracy and efficiency, especially in extremely complex scenes.

Precaution:

- For data collection, establish a cooperative relationship with the School of Civil Engineering in advance to ensure that appropriate equipment is available to obtain the required image data. Also, consider using publicly available datasets as a supplement.
- For algorithm optimization, an iterative R&D process is adopted to regularly evaluate algorithm performance and adjust the optimization direction based on intermediate results. At the same time, keep track of the latest research results so that new solutions can be introduced promptly.

5.2 Time Risk

Research progress delays: Research progress is behind schedule due to technical challenges, difficulty in data collection, or delays in partner response.

Precaution:

Establish an appropriate research plan timeline, including specific goals and milestones for each phase, as well as buffer time.

Implement strict project management and regular reviews to ensure that potential delay factors are discovered on time and corrective measures are taken.

5.3 Other Potential Risk

Equipment failure: Computer hardware, 3D scanning equipment, or other specialized equipment required for research may malfunction.

Mental health issues: During the project implementation, I may encounter extremely unsatisfactory progress and overload of pressure, which affects the continuity of the research.

Precaution:

- In terms of equipment, perform regular equipment inspections and maintenance to ensure that all equipment is in good condition. At the same time, establish a contingency plan for equipment failure, including backup equipment or channels for rapid repair.
- In terms of mental health, do regular outdoor exercise to relieve anxiety. Or seek help from Curtin Counseling Center.

Through these risk assessments and response strategies, possible challenges can be prepared in advance to ensure that this research can proceed smoothly and be completed as planned as possible.

6. Research Ethics

This research obeys ethical principles about computing in Australia.

All data are legally obtained from public data. The obtained data would be ensured that it does not contain sensitive or personal information. The data use license would confirm whether it permits the research to be done and whether any output complies with copyright and usage conditions. The obtained data is evaluated so that it is not misused or misrepresented.

This study does not involve human or animal subjects, confidential information, hazardous equipment or substances, or any other ethical implications.

7. Timeline

The timeline of this research is as follows:

Term	Task/Activity	2024										2025					
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Term 1	Literature searches and taking notes of core materials																
	Research question refine																
	Research proposal writing																
	Preliminary results output																
	Any risk assessment, ethics, approvals etc.																
Term 2	Initial implementation																
	Data and algorithm analysis and comparing																
	The specific direction of optimization determine																
Term 3	Algorithm optimization																
	Optimized algorithm implementation																
	Thesis writing																

Reference

'3D Reconstruction'. 2023. In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=3D_reconstruction&oldid=1192066416.

'3-D Reconstruction - Latest Research and News | Nature'. n.d. Accessed 4 April 2024. https://www.nature.com/subjects/3d-reconstruction.

Abreu de Souza, Mauren, Daoana Carolaine Alka Cordeiro, Jonathan de Oliveira, Mateus Ferro Antunes de Oliveira, and Beatriz Leandro Bonafini. 2023. '3D Multi-Modality Medical Imaging: Combining Anatomical and Infrared Thermal Images for 3D Reconstruction'. *Sensors* 23 (3): 1610. https://doi.org/10.3390/s23031610.

Bebie, T., and H. Bieri. 2000. 'A Video-Based 3D-Reconstruction of Soccer Games'. *Computer Graphics Forum* 19 (3): 391–400. https://doi.org/10.1111/1467-8659.00431.

Cheng, Min-Lung, Masashi Matsuoka, Wen Liu, and Fumio Yamazaki. 2022. 'Near-Real-Time Gradually Expanding 3D Land Surface Reconstruction in Disaster Areas by Sequential Drone Imagery'. *Automation in Construction* 135 (March): 104105. https://doi.org/10.1016/j.autcon.2021.104105.

Fathi, Habib, Fei Dai, and Manolis Lourakis. 2015. 'Automated As-Built 3D Reconstruction of Civil Infrastructure Using Computer Vision: Achievements, Opportunities, and Challenges'. *Advanced Engineering Informatics*, Infrastructure Computer Vision, 29 (2): 149–61. https://doi.org/10.1016/j.aei.2015.01.012.

Feng, Qiaojun, and Nikolay Atanasov. 2021. 'Mesh Reconstruction from Aerial Images for Outdoor Terrain Mapping Using Joint 2D-3D Learning'. In *2021 IEEE International Conference on Robotics and Automation (ICRA)*, 5208–14. https://doi.org/10.1109/ICRA48506.2021.9561337.

Fischer, A., and A. Manor. 1999. 'Utilizing Image Processing Techniques for 3D Reconstruction of Laser-Scanned Data'. *CIRP Annals* 48 (1): 99–102. https://doi.org/10.1016/S0007-8506(07)63140-0.

Gregor, Robert, Ivan Sipiran, Georgios Papaioannou, Tobias Schreck, Anthousis Andreadis, and Pavlos Mavridis. 2014. 'Towards Automated 3D Reconstruction of Defective Cultural Heritage Objects'. *Eurographics Workshop on Graphics and Cultural Heritage*, 10 pages. https://doi.org/10.2312/GCH.20141311.

Haibo, Yang. 2017. 'Industrial Design Applications of Surface Reconstruction Algorithm Based on Three Dimensional Point Cloud Data'. In *2017 International Conference on Robots & Intelligent System (ICRIS)*, 178–81. https://doi.org/10.1109/ICRIS.2017.51.

Han, Xian-Feng, Hamid Laga, and Mohammed Bennamoun. 2021. 'Image-Based 3D Object Reconstruction: State-of-the-Art and Trends in the Deep Learning Era'. *IEEE Transactions on Pattern Analysis and Machine Intelligence* 43 (5): 1578–1604. https://doi.org/10.1109/TPAMI.2019.2954885.

Heide, Felix, Lei Xiao, Wolfgang Heidrich, and Matthias B. Hullin. 2014. 'Diffuse Mirrors: 3D Reconstruction from Diffuse Indirect Illumination Using Inexpensive Time-of-Flight Sensors'. In , 3222–29. https://www.cv-foundation.org/openaccess/content_cvpr_2014/html/Heide_Diffuse_Mirrors_3D_2014_CVPR_paper.html.

Jiang, Weiguang, Ying Zhou, Lieyun Ding, Cheng Zhou, and Xiaodi Ning. 2020. 'UAV-Based 3D Reconstruction for Hoist Site Mapping and Layout Planning in Petrochemical Construction'. *Automation in Construction* 113 (May): 103137. https://doi.org/10.1016/j.autcon.2020.103137.

Kang, Zhizhong, Juntao Yang, Zhou Yang, and Sai Cheng. 2020. 'A Review of Techniques for 3D Reconstruction of Indoor Environments'. *ISPRS International Journal of Geo-Information* 9 (5): 330. https://doi.org/10.3390/ijgi9050330.

Khilar, Rashmita, S. Chitrakala, and SurenderNath SelvamParvathy. 2013. '3D Image Reconstruction: Techniques, Applications and Challenges'. In *2013 International Conference on Optical Imaging Sensor and Security (ICOSS)*, 1–6. https://doi.org/10.1109/ICOISS.2013.6678395.

Li, Ying, Zhijie Zhao, Jiahao Fan, and Wenyue Li. 2022. 'ADR-MVSNet: A Cascade Network for 3D Point Cloud Reconstruction with Pixel Occlusion'. *Pattern Recognition* 125 (May): 108516. https://doi.org/10.1016/j.patcog.2021.108516.

Liu, Caixia, Dehui Kong, Shaofan Wang, Zhiyong Wang, Jinghua Li, and Baocai Yin. 2021. 'Deep3D Reconstruction: Methods, Data, and Challenges'. *Frontiers of Information Technology & Electronic Engineering* 22 (5): 652–72. https://doi.org/10.1631/FITEE.2000068.

Liu, Sheng, Xiaohan Nie, and Raffay Hamid. 2022. 'Depth-Guided Sparse Structure-From-Motion for Movies and TV Shows'. In , 15980–89. https://openaccess.thecvf.com/content/CVPR2022/html/Liu_Depth-Guided_Sparse_Structure-From-Motion_for_Movies_and_TV_Shows_CVPR_2022_paper.html.

Liu, Weiping, Jia Sun, Wanyi Li, Ting Hu, and Peng Wang. 2019. 'Deep Learning on Point Clouds and Its Application: A Survey'. *Sensors* 19 (19): 4188. https://doi.org/10.3390/s19194188.

Lu, Qiuchen, and Sanghoon Lee. 2017. 'Image-Based Technologies for Constructing As-Is Building Information Models for Existing Buildings'. *Journal of Computing in Civil Engineering* 31 (4): 04017005. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000652.

Ma, Duo, Hongyuan Fang, Niannian Wang, Gaozhao Pang, Bin Li, Jiaxiu Dong, and Xue Jiang. 2023. 'A Low-Cost 3D Reconstruction and Measurement System Based on Structure-from-Motion (SFM) and Multi-View Stereo (MVS) for Sewer Pipelines'. *Tunnelling and Underground Space Technology* 141 (November): 105345. https://doi.org/10.1016/j.tust.2023.105345.

Ma, Zhiliang, and Shilong Liu. 2018. 'A Review of 3D Reconstruction Techniques in Civil Engineering and Their Applications'. *Advanced Engineering Informatics* 37 (August): 163–74. https://doi.org/10.1016/j.aei.2018.05.005.

Paoli, Alessandro, Paolo Neri, Armando V. Razionale, Francesco Tamburrino, and Sandro Barone. 2020. 'Sensor Architectures and Technologies for Upper Limb 3D Surface Reconstruction: A Review'. *Sensors* 20 (22): 6584. https://doi.org/10.3390/s20226584.

Poullis, Charalambos, and Suya You. 2011. '3D Reconstruction of Urban Areas'. In *Visualization and Transmission 2011 International Conference on 3D Imaging, Modeling, Processing*, 33–40. https://doi.org/10.1109/3DIMPVT.2011.14.

Ragia, Lemonia, Froso Sarri, and Katerina Mania. 2015. '3D Reconstruction and Visualization of

Alternatives for Restoration of Historic Buildings: A New Approach'. In *2015 1st International Conference on Geographical Information Systems Theory, Applications and Management (GISTAM)*, 1–9. https://ieeexplore.ieee.org/abstract/document/7512211?casa_token=jr76KV47W_8AAAAA:nbiQhYOk-vW2WikLN5_TE8VyKhsjEiDx1DREk0CNjCDlp3_UTsJH3VIYfNU4MIFb6xbxs73cI_2-.

Remondino, Fabio. 2003. 'From Point Cloud to Surface: The Modeling and Visualization Problem'. In *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. Vol. XXXIV-5/W10. ISPRS. https://doi.org/10.3929/ethz-a-004655782.

Shang, Jiaxiang, Tianwei Shen, Shiwei Li, Lei Zhou, Mingmin Zhen, Tian Fang, and Long Quan. 2020. 'Self-Supervised Monocular 3D Face Reconstruction by Occlusion-Aware Multi-View Geometry Consistency'. In *Computer Vision – ECCV 2020*, edited by Andrea Vedaldi, Horst Bischof, Thomas Brox, and Jan-Michael Frahm, 53–70. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-58555-6_4.

Wang, Jiyao, Qilin Zhang, Bin Yang, and Binghan Zhang. 2023. 'Vision-Based Automated Recognition and 3D Localization Framework for Tower Cranes Using Far-Field Cameras'. *Sensors* 23 (10): 4851. https://doi.org/10.3390/s23104851.

Wang, Shuzhe, Vincent Leroy, Yohann Cabon, Boris Chidlovskii, and Jerome Revaud. 2023. 'DUSt3R: Geometric 3D Vision Made Easy'. arXiv. https://doi.org/10.48550/arXiv.2312.14132.

Wang, Yi, Zhiqiang (John) Zhai, and Yu Xue. 2022. 'A City-Scale Inverse Modelling Method for Air Pollutant Source Determination'. *Sustainable Cities and Society* 87 (December): 104248. https://doi.org/10.1016/j.scs.2022.104248.

Xu, Yusheng, Xiaohua Tong, and Uwe Stilla. 2021. 'Voxel-Based Representation of 3D Point Clouds: Methods, Applications, and Its Potential Use in the Construction Industry'. *Automation in Construction* 126 (June): 103675. https://doi.org/10.1016/j.autcon.2021.103675.

Xue, Jingguo, Xueliang Hou, and Ying Zeng. 2021. 'Review of Image-Based 3D Reconstruction of Building for Automated Construction Progress Monitoring'. *Applied Sciences* 11 (17): 7840. https://doi.org/10.3390/app11177840.

Yamazaki, Fumio, Kasumi Kubo, Ryoto Tanabe, and Wen Liu. 2017. 'Damage Assessment and 3d Modeling by UAV Flights after the 2016 Kumamoto, Japan Earthquake'. In *2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, 3182–85. https://doi.org/10.1109/IGARSS.2017.8127673.

Zhang, Song. 2018. 'High-Speed 3D Shape Measurement with Structured Light Methods: A Review'. *Optics and Lasers in Engineering* 106 (July): 119–31. https://doi.org/10.1016/j.optlaseng.2018.02.017.

Zollhöfer, Michael, Patrick Stotko, Andreas Görlitz, Christian Theobalt, Matthias Nießner, Reinhard Klein, and Andreas Kolb. 2018. 'State of the Art on 3D Reconstruction with RGB-D Cameras'. *Computer Graphics Forum* 37 (2): 625–52. https://doi.org/10.1111/cgf.13386.