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Project Methodology and Workflow for Emergency Drone Recording and Processing: Case study Colonial Ammunition Company Shot Tower, Aotearoa New Zealand

The paper explains the methodology and workflow for the emergency drone recording and processing applied in the Colonial Ammunition Company Shot Tower case study in Auckland, Aotearoa New Zealand. It sheds light on the strategic decisions employed during the drone scan and following data processing under significant limitations. The imperfections in data capture and processing, driven by real-world constraints, present valuable lessons for future endeavours. By capturing the intricacies of this emergency documentation process, the paper aims to contribute valuable insights and replicable workflows to the broader field of heritage preservation. The intersection of technology, urgency, and collaboration showcased in this case study opens avenues for refining methodologies, incorporating advancements, and developing standardised processes for heritage preservation in emergency scenarios.

By initiating a broader discourse on the need for standardised processes, collaboration frameworks, and technological advancements in heritage preservation, this paper contributes to this relevant and necessary topic that has not received much attention in academia so far. This paper contributes not only to a case study but is a call to action for developing comprehensive frameworks that empower heritage preservation in the digital age. Shot Tower's challenges and the final demolition in February 2023 serve as a microcosm of the larger issues confronting heritage sites in Aotearoa New Zealand — issues that demand systematic solutions and a coordinated effort from the various entities entrusted with heritage management.

Keywords:
Heritage preservation; technological innovation; emergency heritage documentation process; UAV photogrammetry; Aotearoa New Zealand

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INTRODUCTION

Cultural and natural heritage, embodying both historical significance and environmental importance, faces unprecedented threats in the contemporary world. The challenges of rapid urbanisation, climate change, natural disasters, socio-political upheavals, and insufficient public awareness collectively jeopardise the preservation of tangible heritage assets. Nowhere is this struggle more apparent than in Aotearoa New Zealand, where the vulnerability of heritage sites is exacerbated by disparate regulations, lacking public awareness, and the aftermath of recent seismic events.
The seismic events, exemplified by the Seddon and Kaikōura earthquakes from 2011 to 2016, have left an indelible mark on New Zealand's heritage landscape. The loss of 140 heritage buildings, coupled with relentless redevelopment, underscores the urgency of addressing heritage preservation in the face of evolving challenges (Strengthening protections for heritage buildings: Report identifying issues within New Zealand's heritage protection system, November 2018 2021, p.8). The regulatory landscape, marked by a lack of synchronisation and direction among heritage management organisations (Hamilton and Jadresin Milic, 2020) (Besen et.al., 2020), further compounds the issue, leaving numerous culturally significant buildings unrecognised and unprotected (Jadresin Milic et.al., 2022).
This paper, poised at the intersection of heritage preservation and technological innovation, presents a compelling case study: the emergency drone recording and processing of the Colonial Ammunition Company Shot Tower in Mount Eden, Auckland. Faced with the imminent threat of Cyclone Gabrielle and the subsequent decision to demolish the Shot Tower, a collaboration between Auckland Council, Unitec-Te Pūkenga, and Massey University sought to employ cutting-edge technology to digitally preserve this iconic heritage site (Shot Tower saved for History 2023).
In navigating the urgent need for documentation in emergency situations, the paper elucidates the

Fig. 1 - Colonial Ammunition Shot Tower. Photo Credit Renata Jadresin Milic, February 2023

methodology employed during the drone scan, shedding light on the strategic decisions made under time constraints and limited access. By capturing the intricacies of this emergency documentation process, the paper aims to contribute valuable insights and replicable workflows to the broader field of heritage preservation.
As Aotearoa New Zealand grapples with the ongoing loss and degradation of its cultural heritage, the Shot Tower stands as a poignant example of the broader challenges faced by heritage sites across the nation. This paper not only delves into the practical aspects of emergency drone recording but also endeavours to ignite a larger conversation about the need for standardised processes, collaborative frameworks, and technological advancements in heritage preservation (Laing, 2020) - a discussion crucial for safeguarding our shared cultural legacy in an ever-evolving world.

BACKGROUND: NEW ZEALAND'S LAST STANDING SHOT TOWER

Colonial Ammunition Company Shot Tower (1916) in Auckland was the only twentieth-century shot tower in Australasia and the last shot tower standing in Aotearoa New Zealand. Believed to be the only steel-framed tower of its kind in the Southern Hemisphere and unlike the brick towers in Australia and other parts of the world, it was a rare example internationally to have been built using steel-framed construction (Museum to acquire historic weathervane from CAC Shot Tower 2023). Valuable as a distinctive landmark which reflects the industrial history of the local area (Pfeiffer, 1989), the tower was further evidence of local resourcefulness in its construction. It is a reminder of the country's involvement during the First World War and its tradition of hunting and shooting for sport, which directly stems from its colonial and Māori past (Colonial Ammunition Company Shot Tower. Heritage New Zealand Pouhere Taonga). As such, the Shot Tower was of national and international importance.
Built about 1916, the tower was designed to produce lead shots for shotgun cartridges, used in hunting and sports. As the first munitions factory in Australasia, the Colonial Ammunition Company founded the sprawling industrial complex in the Mt Eden neighbourhood of Auckland in the mid-1880s. Producing mainly military ammunition, its early manufacture of shotgun cartridges at Mt Eden was small-scale, using shots made in the South Island. The company set out to compete with British-made imports that supplied the majority of the 9 million shotgun cartridges used an-

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Fig. 2 - Processed Photogrammetry Point Cloud. Rendered in Reality Capture – Credit Sam Smith - WOODS

nually in New Zealand, as demand for its military products surged during the First World War. The shot tower helped the facility maintain high output levels even after the war (Colonial Ammunition Company Shot Tower. Heritage New Zealand Pouhere Taonga).

The tower was approximately 35 m tall and consisted of a polygonal room clad in corrugated iron, supported on a steel frame. Local blacksmiths built the structure. Melted lead was passed through a sieve at the top of the tower, and as it fell into a room at the foot of the tower filled with water, it solidified (Pfeiffer, 1989, p.54). After that, the shot was graded, polished, and kept in related corrugated iron structures attached to the tower, and recycled if imperfect. As shot production advanced, the tower and its associated structures underwent modifications until the CAC left the location in the 1980s. In 2001, the buildings at its base were removed; nevertheless, the tower survived due to public pressure to preserve it (Colonial Ammunition Company Shot Tower. Heritage New Zealand Pouhere Taonga).

Although listed as a 'Category 1 historic place' on the Heritage New Zealand Pouhere Taonga List, the Shot Tower was not adequately maintained for decades and was deteriorating gradually, presenting itself as an example of the weaknesses of the existing legislation and an apparent anomaly and lack of synchronisation and direction between different organisations that manage heritage in this country (Strengthening protections for heritage buildings: Report identifying issues within New Zealand's heritage protection system, November 2018 2021, p.8); (Jadresin Milic et al., 2022).

Eventually, in February 2023, ahead of threats from Cyclone Gabrielle, engineers determined that the Tower was a risk to life and property (Figure 1). The urgency of the work arose out of concerns that the Tower's structure could collapse under the anticipated wind loads from Cyclone Gabrielle (Drone footage used to make digital record of New Zealand's last standing shot tower 2023). Because of extensive corrosion and poor structural integrity of the structure, time was of the essence due to safety concerns (Demolition of Colonial Ammunition Company Shot Tower to begin Tuesday 2023). The Auckland Council decided to evacuate the immediate area and to proceed with plans for its demolition. This decision meant that 50 apartments needed to be evacuated, which added to the urgency to complete the scanning (Demolition of Colonial Ammunition Company Shot Tower to begin Tuesday 2023). The Tower was demolished later in February 2023 (Museum to acquire historic weathervane from CAC Shot Tower 2023).

Auckland Council partnered with the School of Architecture at Unitec-Te Pūkenga and the School of the Built Environment at Massey University to conduct a drone scan of the historic Colonial Ammunition Company Shot Tower (Shot Tower saved for History 2023). By conducting the urgent drone scan (Drone footage used to make digital record of New Zealand's last standing shot tower 2023) of this Category 1 heritage site, a permanent digital record of the structure and its site was done, digital preservation of an essential piece of Auckland's history was accomplished, and the value of using cutting-edge technology to document and understand our past was demonstrated (Museum to acquire historic weathervane from CAC Shot Tower 2023). The drone scan captured detailed images and data of the Tower and its surroundings. The drone's flight path was planned to ensure all the necessary angles and details were captured, including close-up shots of any historic features or signage and wider shots that placed the building in its historical context. All of this had to be achieved while working outside the 35-metre drop zone of the Tower (Shot Tower saved for History 2023).

With the scanning completed, the data was post-processed to produce the point clouds (Figure 2) and digital copies of the Shot Tower. The aim was to develop a 3D model (Figure 3) and a virtual tour which could be accessed by future researchers and the general public.

MATERIALS AND METHODS (METHODOLOGY)

Workflow in the Data Capturing

The drone scanning methodology employed for the emergency documentation of the Shot Tower was carefully designed to address the unique challenges posed by the imminent threat of Cyclone Gabrielle, the limited time for planning, and the urgency of preserving the heritage site. Hence, the emergency drone recording and processing of the Shot Tower was not without its operational challenges, prompting strategic decisions in response to the unique site constraints. With a 35-metre drop zone perimeter encircling the tower and limited access points due to adjacent apartment buildings, a drone emerged as the most viable solution. The tower's vertical nature

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and the obstructed sides by the apartment building rendered droning from the outside imperative. The complexity escalated as the tower was situated near the Auckland Central Remand Prison in Mount Eden. Clearance had to be sought from the prison authorities to fly. Fortunately, the timing aligned favourably with days preceding the expected cyclone, featuring light wind levels and no rain, providing a window of opportunity to deploy the drone.
Moreover, the necessity to maintain a 35-metre stand-off from the tower precluded the option of flying inside the structure. This constraint shaped the operational approach, emphasizing external droning as the exclusive method. These considerations underscore the intricate dance between site-specific limitations and operational decisions, showcasing the dynamic nature of emergency heritage documentation.
The workflow in the data capturing was:

1. Choice of Drone: The DJI Mavic Pro UAV was selected for its agility, ease of use, and rapid deployment capabilities. Its ability to capture high-resolution video footage provided a practical solution for quick data acquisition. Moreover, it was expendable, and if something happened, its loss could be accepted.
2. Video Footage Capture: Given the urgency of the situation, video footage was chosen as the primary data capture method. The drone executed vertical passes up the shot tower structure, covering various aspects of the tower from the ground up to the top. This approach allowed for a comprehensive view of the tower while adhering to safety considerations. It also gave a record that could be easily featured on websites and in exhibits.
3. Frame Extraction: Video frames were extracted at a rate of one frame every fourth second, resulting in approximately 60-90 seconds of footage for each pass. This frame extraction method balanced the need for adequate coverage with the limited time available for data capture.
4. Nadir and Oblique Imaging: The capture strategy included both nadir (perpendicular to the ground) and oblique (at angles other than perpendicular) imaging. Nadir imagery provided essential GPS metadata for georeferencing, while oblique imagery offered additional perspectives for a holistic understanding of the tower's structure.

The main limitations that caused the workflow explained above were:

1. Time Constraints: The urgency imposed by the impending cyclone necessitated a rapid and efficient data capture process. The UAV's quick deployment and video recording capabilities allowed the team to initiate the scanning process promptly.
2. Limited Access to the Site: The restricted access to the site posed challenges for the careful planning and execution of traditional surveying methods. The drone offered a practical solution to capture data from various angles, overcoming potential obstacles on the ground.
3. Safety Concerns: The structural instability of the shot tower, coupled with the need to evacuate nearby apartments, emphasized the importance of a non-intrusive data capture method. The drone's capability to operate from a safe distance ensured the safety of both the operators and the surrounding area.
4. Resource Mobilization: The use of a consumer-grade UAV aligned with resource constraints and the need for a quick response. The methodology focused on leveraging available tools and technologies to maximize the data capture within the limited timeframe. (Boardman & Bryan, 2018)

In summary, the chosen drone scanning methodology was a pragmatic response to the specific challenges posed by the emergency. The rapid deployment, flexibility in capturing video footage, and adherence to safety considerations were key factors influencing the decision-making process. The methodology aimed to balance the trade-offs between time constraints, resource availability, and the imperative to document the heritage site before potential loss or damage.

Fig. 3 - Colonial Ammunition Shot Tower. Rendered Photogrammetry Mesh – Credit Sam Smith and Maksym Khovalko, model based on drone recording by Regan Potangaroa and Renata Jadresin-Milic, 2023

Workflow in the Data Processing

Photogrammetry relies on imaging an object or feature from a varying number of heights and aspects to capture a 3-Dimensional record. Captured images can then be processed using a method known as pixel correlation which in essence explodes each image into their individual pixels, matches these pixels against corresponding pixels from other exploded images, and then reassembles them into a consolidated 3-Dimensional dataset (Bedford, 2017).

Data Received

- Capture Equipment: DJI Mavic Pro UAV
- Data Recieved: MPEG 4 video (17 videos) – 1080p resolution, 25 frames per second; Frames extracted - ~1980 approx.; JPEG Imagery (96 Images) – Nadir Aspect with GPS Metadata.

The ideal capture methodology for digital heritage preservation for a site such as this uses a com-

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bination of LiDAR scanning, UAV photogrammetry and terrestrial photography (Boardman & Bryan, 2018). Given the timing and resources available, only a UAV capture was possible at the time.

UAV Photogrammetry consists of two specific imaging types.

- Nadir – Lens direction perpendicular to the ground
- Oblique – Lens direction at any other angle than perpendicular to the ground

The preferred capture flight path would be an orbit around the feature of interest, capturing overlapping images around the object of interest.

While there was a good collection of Nadir imagery, the remaining UAV capture consisted of only video footage. This video footage was made up of several of vertical passes up the shot tower structure. Generally, this pass was from the ground up to the highest point, although the closeness of the apartment structures on two sides prevented UAV capture from some angles at lower elevations. The passes were approximately 60-90 seconds long and were at a slow pace, which was ideal for limiting blurring when it came time to process these videos into the model.

There are three main disadvantages to using video footage:

Firstly, video footage does not have the GPS location of each individual frame stamped on it.

Instead, the GPS location is typically stamped at the time the 'record' button is triggered. This is opposed to the Nadir flight, whereby each individual image is stamped with a GPS position, which greatly assists the image-matching process. GPS metadata is not critical, although GPS stamping on images is incredibly advantageous in photogrammetry processing as it shortens what can be lengthy calculation timeframes and can assist in matching nearby images which may have less than the desired overlap between them. To ensure there is good overlap for photogrammetry matching on the video frames, more frames need to be extracted closer together.

Secondly, Photogrammetric matching of video footage involves extracting single frames from the video footage and saving them as images. Frame rates for video recording can vary, but in this instance, the video was captured at 25 frames per second, and our frame extraction took every third frame. The DJI Mavic Pro UAV captured the video footage at a 1080p resolution, which means video frames are 1920 pixels wide by 1080 pixels high. A static image from the same camera on the Phantom 4 would be 4000 pixels wide by 3000 pixels high. Effectively, we have half the number of pixels to work with by using the frame extraction method, which impacts pixel resolution, image quality and point cloud accuracy. For photogrammetry, pixel count is critical because it translates to a greater level of detail in the pixel correlation calculations and clarity applied to an image. By not having supporting LiDAR data, every pixel was important. Fortunately, the UAV video was captured at close enough proximity to the tower that there was adequate detail for pixel matching, and the production of a good quality mesh and texture map, although not a maximum quality one. This proximity of the UAV to the tower would present different challenges later, but this was a good trade-off to make in the circumstances.

Finally, photogrammetry relies on large amounts of overlap between images to find enough coincident points to reconstruct in 3D. Because images are typically wider than they are high, vertical overlap is typically more challenging to achieve than horizontal overlap; understanding that images extracted from video footage are already smaller than desired, to maintain enough overlap can become difficult. Because the videography was a collection of vertical passes, more frames were required to be extracted to maintain enough overlap for pixel matching. As an alternative, if a circular 'Area of Interest' capture was undertaken using static images over video, matching could have used the GPS position of the images while leveraging the horizontal overlap of the images to achieve a similar result with fewer inputs.

Image Matching and Photogrammetric Processing

- Processing Software: RealityCapture (www.capturingreality.com)

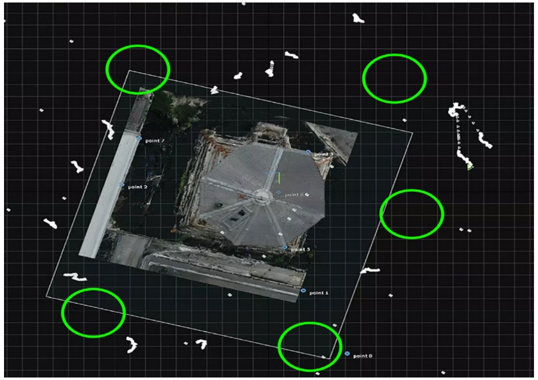

Fig. 4 - Colonial Ammunition Shot Tower. Plan view of processed photogrammetry images in Reality Capture with green rings representing gaps in image overlap for pixel matching – Credit Sam Smith - WOODS.

- Import Settings: Image Overlap Setting - Low Overlap
  Image Downscaling - No Downscaling
  Distortion Model - Brown 3 with Tangential 2
- Control Points: 9 Manual Control Points to tie three model components together

The video footage was imported into Reality Capture. Every 4th frame was extracted from the video for matching. The video footage consisted of approximately 60-second clips from a number of aspects of the shot tower where the UAV flew from the ground up to the top of the shot tower. This resulted in between 200 and 300 frames for each video segment.

After importing all of the video footage and extracting the required frames, an initial image alignment process was done. Image alignment was done using a 'Low Overlap' setting to account for the relatively low image resolution and to bridge any possible gaps when matching horizontally. The initial matching resulted in three components consisting of the Aerial Nadir, and two separate components making up the vertical passes of the tower. It was anticipated that the Aerial Nadir would be separated as these images contained GPS metadata,

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while the video footage was in a localised, or Euclidean, coordinate system. The proximity of the UAV to the tower was approximately 5-10m too close in collection for alignment – but acceptable, as mentioned above – this meant that it was very difficult to find enough coincident points on buildings and features around the shot tower for algorithmic matching to some of the adjacent vertical passes, which was the main factor in the creation of two separate components for the oblique imagery of the tower.

As there wasn't enough horizontal overlap between images from neighbouring vertical passes, a number of manual constraints were created to assist with the automatic pixel matching process. Due to the close proximity of the UAV to the tower, there were limited control points we could identify for the secondary phase of matching. The primary issue was that because the tower occupied so much of the frame, many contextual features around it were obstructed by the tower, or out of frame on the neighbouring video.

The Green Circles (Figure 4) indicate the areas where the horizontal image overlap was insufficient for matching into a single component, and additional control points needed to be created.

With the assistance of the Nadir imagery, and a rigorous control point selection process, we were able to identify nine coincident control points between each of the three components that we could use to tie these together.

Figure 5 shows the Nadir Images at the top (orange lines with white dots at the end), and the frames extracted from the video footage (white dots). The blue markers indicate the manual tie points that were used to match the three components and create the completed dataset.

In total, 1.49 million points were generated for the resulting point cloud with a pixel resolution of approximately 20mm (1 pixel is 20 millimetres wide). A higher pixel resolution and lower mean error might have been achieved with LiDAR scan data included, but given the constraints and challenges in the capture process, this was an acceptable result.

Mesh Calculation and Production

Using the point cloud generated during processing, a mesh calculation process was undertaken. This dataset consisted of 10.3 million vertices to build a 20.5 million triangle mesh of the tower. Because of the apartment buildings on two aspects of the tower, the bottom half of the tower and the pipe section had an incomplete or distorted mesh below the roofline of the apartment buildings. While the main structure was sufficiently detailed, the ladder going up the tower and weathervane on top didn't have the necessary point data to adequately mesh firstly the ladder, and secondly the weathervane itself.

After the mesh was created, a full-resolution texture map was also created to bake onto the mesh model. At this point, the images can be down-sampled to balance detail and texture file sizes; given the pixel size of the extracted frames, it was determined that no image down-sampling should take place to preserve as much image detail as possible. This full-resolution texture map could then be applied to a more simplified mesh later.

At 20.5 million triangles, the model was too large for any practical application, so a process of simplification was undertaken.

This process involves a best practice of optimising the mesh by halving the target triangle count before checking the mesh's integrity, topology and filling any holes that might be created in the mesh during the simplification process. It is possible to simplify the mesh by other factors, but this can have unexpected results in the simplification process.

Typically, a mesh consisting of 1 million triangles is suitable for 3D Animation, third-party rendering software and, to a lesser degree, video game applications. In the case of interactive experiences such as video games and Virtual Reality, fewer triangles improve the relative performance of the application running it, which in turn improves the relative experience of the user; it is a balance to strike between experiencing the highest degree of detail without spoiling the experience through poor system performance.

To upload the model to an online platform such as SketchFab, a target triangle count of approximately 150,000 is necessary to produce a mesh and 16k texture file and come in under the 200Mb File Size limit imposed by the platform. This would require eight simplification procedures to achieve our target. Ultimately, ten simplifications were required due to the simplification process failing

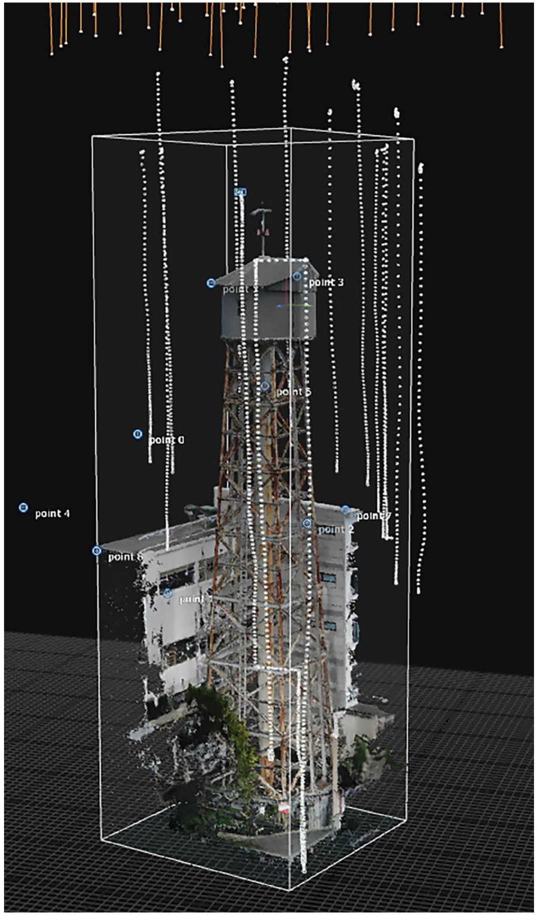

Fig. 5 - Perspective View of Auckland Colonial Shot Tower processed in reality capture showing vertical image alignment – Credit Sam Smith – WOODS

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between 325,000 triangles and 150,000 triangles. Two extra calculations were done to resolve this: a 300,000-triangle mesh, a 275,000-triangle mesh, and the final 150,000-triangle mesh. (Figure 6)
After the mesh simplification was completed and verified, the full-resolution texture map created for the 20.5 million triangle model was then recalculated and projected onto the simplified mesh. Smoothing the mesh would also be normally done on meshes such as these. However, given the degradation in some of the more detailed elements of the mesh (see the weathervane in the Figure 7), the un-smoothed model was used for the final result.

RESULTS AND DISCUSSION: NAVIGATING IMPERFECTION FOR HERITAGE PRESERVATION

Capturing the Essence: Drone Scanning Methodology

The urgency imposed by Cyclone Gabrielle necessitated a departure from conventional heritage documentation practices, leading to the adoption of drone scanning for the Colonial Ammunition Company Shot Tower. The drone's flight path, meticulously planned to avoid the 35-metre drop zone, enabled the capture of detailed images and data, preserving the essence of the tower and its surroundings. However, the emergency nature of the situation posed challenges, limiting access and time for careful planning. The team utilised the available tools and expertise under these constraints, emphasising the need for adaptability in emergency heritage documentation.

Workflow Challenges in Data Processing

The subsequent data processing phase confronted unique challenges stemming from the use of video footage for photogrammetry. While traditional methods advocate for static imagery with GPS metadata, the urgency of the situation dictated the use of video captured by a DJI Mavic Pro UAV. The extraction of frames from video footage, albeit at a reduced pixel count, presented hurdles in pixel resolution, image quality, and point cloud accuracy. The absence of GPS metadata for each frame added complexity to the image-matching process, emphasising the trade-offs made under time constraints.

Overcoming Obstacles in Image Matching

Photogrammetric processing faced hurdles due to the vertical passes of the tower captured through video footage. Limited horizontal overlap and obstruction of contextual features necessitated manual constraints for image matching. The meticulous identification of control points using Nadir imagery facilitated the alignment of three separate components, creating a cohesive dataset. The resultant point cloud, comprising 1.49 million points with a pixel resolution of approximately 20mm, showcased the successful amalgamation of disparate data sources under challenging circumstances.

Mesh Calculation and Model Optimisation

The creation of a 20.5 million triangle mesh from the point cloud marked a pivotal juncture in the digital preservation process. However, challenges arose in mesh integrity due to incomplete or distorted sections below the roofline of adjacent apartment buildings (Figure 1). The iterative process of mesh simplification, driven by practical considerations of model size and platform constraints, underscored the delicate balance between detail and application performance. The final model, consisting of approximately 150,000 triangles, represented a compromise that met the requirements for online platforms while retaining critical heritage details (Figure 3).

Lessons Learned and Future Prospects

While the results achieved through the proposed workflow may not attain perfection, they underscore the importance of adaptive methodologies in emergency heritage documentation. The imper-

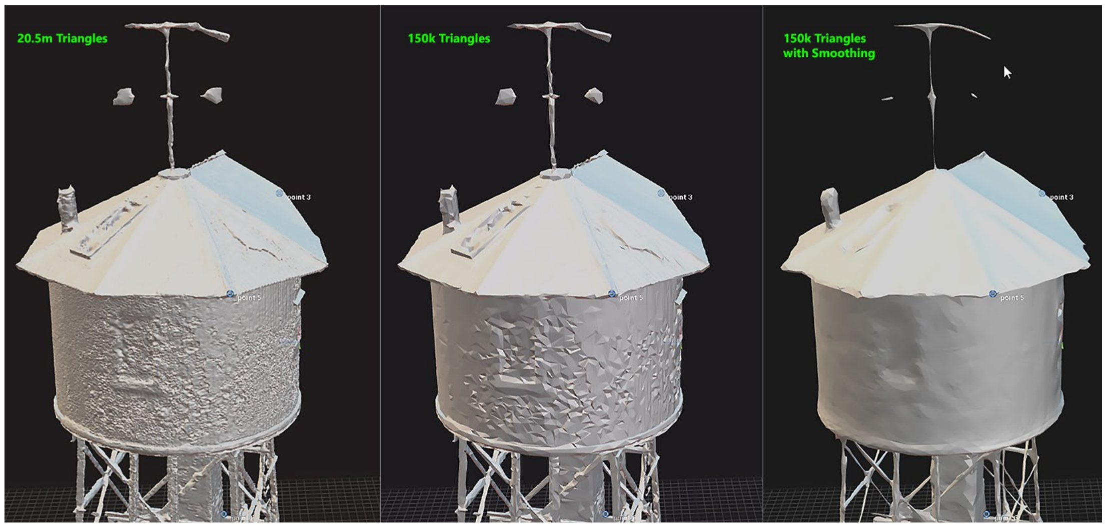

Fig. 6 - Colonial Ammunition Shot Tower. Comparison of mesh detail after simplification. Credit – Sam Smith – WOODS

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fections in data capture and processing, driven by real-world constraints, present valuable lessons for future endeavours. The intersection of technology, urgency, and collaboration showcased in this case study opens avenues for refining methodologies, incorporating advancements, and developing standardised processes for heritage preservation in emergency scenarios.

Future Technological Prospects: Robotic Dogs and Collaborative LIDAR

As we reflect on the emergency drone recording and processing of the Colonial Ammunition Company Shot Tower, it becomes evident that technological advancements continue to reshape the landscape of heritage preservation (Addison, 2000). In envisioning future scenarios, the development of robotic dogs emerges as a promising avenue. Our ongoing efforts to refine this technology open the door to unprecedented possibilities. Imagine a robotic companion, equipped with a LIDAR system, effortlessly navigating within the restricted 35-metre zone of the tower. This collaborative integration of robotic mobility and LIDAR precision could revolutionise emergency heritage documentation, providing a solution that marries accessibility with advanced data capture capabilities. While the drone scan showcased adaptability under constraints, the prospect of leveraging robotic dogs with embedded LIDAR introduces a paradigm shift, promising enhanced efficiency, and data richness in future preservation endeavours. As we continue to evolve our technological toolkit, the synergy between robotics and LIDAR offers a glimpse into the exciting future of heritage documentation. Perhaps, in the next emergency scenario, the robotic dog will stand as a testament to the relentless pursuit of innovation in safeguarding our cultural legacy.

In conclusion, the results and discussion section not only delineate the tangible outcomes of the emergency drone recording and processing but also serves as a reflective platform. It encourages a nuanced understanding of the challenges faced, the trade-offs made, and the potential avenues for improvement in future heritage preservation endeavours under constrained circumstances.

Fig. 7 - Colonial Ammunition Shot Tower. Comparison of textured mesh model after simplification and texture reprojections. Credit – Sam Smith - WOODS

CONCLUSION: CHARTING A COURSE FOR HERITAGE RESILIENCE

In the face of mounting challenges to cultural and natural heritage, this paper has delved into the urgent need for innovative preservation strategies, spotlighted through the lens of the emergency drone recording and processing of the Shot Tower. As the last standing shot tower in Aotearoa New Zealand, its fate epitomises the broader struggles faced by heritage sites nationwide.

The methodology employed in this case study, born out of necessity, and constrained by time and access limitations, offers a blueprint for navigating emergency situations. The intricate dance between the technological advancements in drone scanning, the urgency imposed by Cyclone Gabrielle, and the collaborative efforts of Auckland Council, Unitec-Te Pūkenga, and Massey University demonstrates the potential for marrying innovation with preservation imperatives.

The results, though imperfect, bear witness to the success achieved in digitally preserving a vital piece of Auckland's history. The 3D model generated through the drone scan, despite limitations in pixel resolution and point cloud accuracy, stands as a testament to the resilience of heritage documentation in the face of adversity. It opens avenues for future researchers, historians, and the public to engage with and understand the Shot Tower long after its physical presence has faded.

However, this paper extends beyond the specific case study, aiming to ignite a broader discourse on the need for standardised processes, collaboration frameworks, and technological advancements in heritage preservation (Laing, 2020). The challenges faced by the Shot Tower serve as a microcosm of the larger issues confronting heritage sites in New Zealand — issues that demand systematic solutions and a coordinated effort from

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the various entities entrusted with heritage management.

In conclusion, the imperative to mobilise resources swiftly in the face of imminent heritage loss is underscored. The imperfect capture achieved in this emergency scenario highlights the importance of having predefined plans and procedures, as well as a repository of available equipment and methodologies tailored for such exigencies. This paper contributes not only a case study, but is a call to action for the development of comprehensive frameworks that empower heritage preservation in the digital age.

As technology continues to advance, presenting new opportunities and challenges, the lessons gleaned from the emergency drone recording and processing of the Shot Tower pave the way for a more resilient future for our shared cultural legacy. In this ever-evolving landscape, the commitment to preserving the past remains unwavering, ensuring that heritage, though subject to the passage of time, endures in the collective consciousness of future generations.

REFERENCES

Addison, A. C. (2000). Emerging trends in virtual heritage. I*EEE Multimedia*, 7(2), 22–25.

Antonopoulou, S., & Bryan, P. (2017). *BIM for heritage: Developing a historic building information model*. Historic England. Retrieved December 31, 2023, from http: https://historicengland.org.uk/advice/technical-advice/recording-heritage

Bedford, J. (2017). *Photogrammetric applications for cultural heritage: Guidance for good practice*. Historic England. Retrieved December 31, 2023, from http://historicengland.org.uk/images-books/publications/photogrammetric-applications-for-cultural-heritage/

Besen, P., Boarin, P. & Haarhoff, E. (2020). Energy and Seismic Retrofit of Historic Buildings in New Zealand: Reflections on Current Policies and Practice. *The Historic Environment: Policy & Practice*, 11(1), 91-117

Boardman, C., & Bryan, P. (2018). *3D laser scanning for Heritage: Advice and guidance on the use of laser scanning in archaeology and architecture*. Historic England. Retrieved December 31, 2023, from https://historicengland.org.uk/images-books/publications/3d-laser-scanning-heritage/

Colonial Ammunition Company Shot Tower. Heritage New Zealand Pouhere Taonga. (n.d.). Retrieved December 31, 2023, from https://www.heritage.org.nz/list-details/87/Colonial%20Ammunition%20Company%20Shot%20Tower

Demolition of Colonial Ammunition Company Shot Tower to begin Tuesday. OurAuckland. (2023, February 20). Retrieved December 31, 2023, from https://ourauckland.aucklandcouncil.govt.nz/news/2023/02/demolition-of-colonial-ammunition-company-shot-tower-to-begin-tuesday/

Drone footage used to make digital record of New Zealand's last standing shot tower. Massey News. (2023, March 14). Retrieved December 31, 2023, from https://www.massey.ac.nz/about/news/drone-footage-used-to-make-digital-record-of-new-zealands-last-standing-shot-tower/

Hamilton, J., & Jadresin-Milic, R. (2020). Preservation issues and controversies: Challenges of underutilised and abandoned places. In A. Ghaffarianhoseini, A. Ghaffarianhoseini and N. Nasmith (Eds.), *Imaginable Futures: Design Thinking, and the Scientific Method, 54th International Conference of the Architectural Science Association 2020*, Auckland University of Technology, Auckland, New Zealand (pp. 885-894). Retrieved from https://www.asa2020.net/ Heritage., English, Investment Property Databank., and RICS Foundation. 2002. The Investment Performance of Listed Office Buildings: A Regular Survey. RICS Foundation, 20.legis

Jadresin Milic, R., McPherson, P., McConchie, G., Reutlinger, T., & Singh, S. (2022). Architectural History and Sustainable Architectural Heritage Education: Digitalisation of Heritage in New Zealand. *Sustainability*, 14(24), 16432.

Jadresin Milic, R., Reutlinger T., Singh, S. (2022). "Heritage Bites" - Digital lunchtime talks on historic heritage matters, Historic Places Aotearoa and ICOMOS New Zealand. Accessed November 11, 2023 on https://www.youtube.com/watch?v=ykgOQFzIlbA

Laing, R. (2020). Built Heritage Modelling and visualisation: The potential to engage with issues of heritage value and wider participation. *Developments in the Built Environment*, 4, 100017

Ministry for Culture and Heritage. (2021, October). *Strengthening protections for heritage buildings: Report identifying issues within New Zealand's heritage protection system, November 2018.* Retrieved December 31, 2023, from https://mch.govt.nz/sites/default/files/2023-11/proactive-release-strengthening-protections-for-heritage-buildings-report.pdf

Museum to acquire historic weathervane from CAC Shot Tower. OurAuckland. (2023, April 3). Retrieved December 31, 2023, from https://ourauckland.aucklandcouncil.govt.nz/news/2023/03/museum-to-acquire-historic-weathervane-from-cac-shot-tower/

Pfeiffer, K. (1989). *Historic Buildings of Northland and Auckland: A Register of Classified Buildings*. New Zealand Historic Places Trust.

Shot tower saved for history. (2023, April 20). *Central Leader*, p. 18.

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