Virtual Reconstruction –
The resurrection of the Lyttelton Timeball Station in a Digital Space.

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SUMMARY

The unique nature of this project has pushed the available point cloud data to its limits, driven the development of unique new analysis tools, utilized web-sourced imagery and ultimately benefitted from a great deal of luck.

Following the February 2011 earthquake, the severely damaged remains of the Timeball Station were scanned, never anticipating the application that would ensue for the data. The major earthquake in June 2011 caused the tower to collapse completely, compromising the careful deconstruction and material salvage that was in progress. The rest of the building was subsequently demolished, leaving only the foundations and parts of the ground floor.

The Beca survey team was commissioned in 2014 to scan the site and the foundations in preparation for the design phase. This commission was extended to scan salvaged stone pieces to help the project team save time by avoiding hand measurements and the associated potential for errors. In 2015 each individual facing stone was laid out on the ground, scanned and documented. These limestone pieces were not originally cut to a uniform size and most are quite unique. Our task was to identify, match and place each stone back in its original position to facilitate a virtual rebuild of the tower – a subtle and complex 3D jigsaw puzzle. The project required painstaking digital measurement of every stone and the development of specific software to help with the analysis.

In addition to the stonework, the critical mechanical workings of the Timeball equipment were scanned on the ground and virtually reconstructed to determine their original position within the tower – a process that ultimately relied on the fortuitous availability of a single photograph of the rubble following the collapse of the tower.

SOMMAIRE (French)

La nature unique de ce projet a repousser les limites du nuage de points disponible, nous poussant à développer de nouveau outillés de travail unique, utilisant des images capturant sur le net et finalement bénéficier de beaucoup de chance.

Suivant au tremblement de terre de Février 2011, l'enveloppe gravement endommagé de "Timeball Station" fut scannée, sans se rendre compte de l'implication qu'aura le scan dans la suite du projet.

L’important tremblement de terre de Juin 2011 causa l’effondrement complète et compromettant la minutieuse déconstruction qui était en cour. La suite du bâtiment fut alors démolie et laissant seulement la fondation et le sol visible.

L’équipe de Géomètre de Beca fut alors invite en 2014 à scanner les ruines qui est en préparation pour la reconstruction. L’invitation s’entendit au scan des pierres pour réduire leur manipulation et des mesures à la main qui pourrait induire des erreurs. En 2015 chaque pierres fut aligne sur le sol, scanne et répertorier. Les pierres de calcaire blanc n’étaient pas découper de forme unique mais avec chacune une taille différente. Notre rôle était d’identifier et reconstituer de façon virtuel la reconstruction – un subtil et complexe puzzle 3D. Le projet nous a poussés à prendre les dimensions virtuelles de chaque pierre et de développer un logiciel d’analyse.

En plus du travail de la pierre, l’important mécanisme fessant fonctionner les équipements de Timeball ont été scannée a même le sol et reconstruit virtuellement pour déterminer leur position original dans la tour. Un processus qui se joua seulement a la chance et la disponibilité d’une simple image prise à la suite de l’effondrement de la tour.

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1. AN HISTORICAL LEGACY

Lyttelton has been the location of one of the New Zealand's main ports since the arrival of the first European ships in the mid-1800s. The port processes large volumes of key commodities such as wood and coal as well as being a container terminal, vehicle terminal and an important stop for smaller ships serving other New Zealand destinations. It has been an essential hub for goods feeding into Canterbury's recovery. The town is known for its quirky charm and hosts coffee shops, restaurants, bars, a thriving farmers' market and several historical buildings.

Built in 1876, the Lyttelton Timeball Station (the Timeball) has played an important role in the maritime history of Lyttelton and its harbour. Located on the side of the hill above the harbor, the Timeball has a dominant view over the harbour and was clearly visible to ships coming in and out of the harbour. In the past, the Timeball was one of the most important tools for navigation and exploration in the region. Its significance is easily forgotten in today's world of ubiquitous GPS navigation and precision timekeeping.

The function of the Timeball was to give the exact time of the day to ships in the port by dropping a large round ball down a mast at 1pm each day. Knowledge of time was extremely important for calibrating navigation instruments. Latitude could be measured using a sextant, but longitude was defined by time. An error of few seconds could result in a significant error of position, which could lead to catastrophic consequences.

In 1934, the Timeball as a timekeeping device was replaced by radio signals, but in 1983 the building was classified as Heritage Category 1. At this time the Timeball was the only one to remain in working order in New Zealand, and one of only five worldwide. The distinctive tower with its large red and black ball was an often-photographed landmark in the harbour, a fact that would prove useful during reconstruction efforts.

2. THE FALL OF THE TIMEBALL

In September 2010 the Timeball, like so many other un-reinforced masonry buildings in Canterbury was subjected to damage caused by the first of the Canterbury earthquake sequence. Stones from the building fell, the East façade collapsed and cracks could be observed throughout the building.

During the following months, the building was the subject of detailed repair planning which included controlled deconstruction. The goal was to remove and catalogue every stone and store them carefully for future reconstruction. This plan would allow rebuilding of the Timeball in the shortest and most efficient manner.

In February 2011, Archeological Solutions Ltd laser scanned what remained of the tower and residence building. The structure was still standing but very unstable and the risk of further collapse was high. The purpose of this scan was to monitor the structure of the building, not to create a detailed heritage record. As a consequence, scans were completed from some distance from the building, which was surrounded in places by trees and bushes and not all building faces could be seen. The scan was also not related to any specific height datum.

Sadly, in June 2011 after a significant aftershock, the remaining structure of the Timeball Station collapsed. The collapse removed the need for further monitoring and the scans were set aside. The goal to re-instate this unique piece of history was placed on hold.

However, the story was not over. Heritage New Zealand was able to salvage a significant amount of the original building material including 250 of the original facing stones that gave the Timeball its particular shape and appearance out of a total of approximately 350 stones. These were the large Oamaru stone blocks that run up each corner of the tower and around doors and windows. The salvaged stones were carefully catalogued, but the strong desire to rebuild the Timeball tower as close as physically possible to the original resulted in a project to determine where in the original structure each salvaged stone fitted.

3. THE CHALLENGE

Heritage New Zealand was strongly motivated to see the Timeball resurrected. Beca was engaged to provide project management services and the survey team engaged to provide further laser scanning and data extraction. The challenge was to determine the precise shape and form of the original tower, and identify where each individual stone, now on the ground, belonged back in its original location.

3.2 Map the original structure

With no existing as-built data, key measurements such as tower height, door and window levels, base measurements and shape were unknown. The scan completed in February 2011 became a valuable resource, used for an application far beyond its original purpose.

From this scan data, the dimensions of

every visible facing stone were to be extracted, including width, height and external angle. Using a combination of 3D Reshaper software to create a detailed surface model of the building façade and AutoCAD to extract the dimensions, a catalogue of over 200 stones was created for six of the eight tower facades. This achievement was a starting point for the more intensive stone by stone measurements to follow.

A highly visible outcome of this stage in the project is the architectural model that has been made of the tower using the dimensions derived from the scan data. This model has been used for publicity and to allow people to visualise what the rebuilt tower will look like.

An attempt was made to use crowd-sourced images of the tower to create a 3d model of the tower. This was surprisingly successful but inadequate for accurate mapping, especially considering that the two missing faces were largely unseen on tourist or historic images in any case.

3.3 Model individual stones

After evaluation of the repair strategy, the decision was reached to rebuild the tower and its crowning mast and ball. The major challenge was now to work out how to reassemble the stones lying stored in crates at ground level – essentially rebuilding this giant 3d jigsaw puzzle back into a tower.

The tower contained approximately 350 facing stones but only 250 could be saved following collapse of the building. Many of these had suffered damage so their dimensions would not, in any case, match the originals. Every stone was laid out on the ground and a high-density laser scan of all visible faces completed. In many cases, stones could have been placed upside down, effectively doubling the number of possible scenarios that had to be considered.

Some stones had unique features such as cable attachments or window frame detailing, but 90% did not have enough detail to be easily relocated in the tower. Very quickly it became clear that the exterior corner angles of the octagonal facades were similar (approximately 135 degrees). It was also clear that not every stone had unique dimensions (face lengths and height), so the number of potential locations for each stone became very large. The goal of fitting as many stones back to their original location in the tower would require considerable effort.

Expecting a stone mason to solve this complex 3D jigsaw would make the project near impossible to price and leave it open to cost overruns and delays, so this complex task had to be completed and provided as part of the tender process for stone masons.

More than 300,000 comparisons had to be completed (200 locations extracted from the tower, 250 stones, and three-dimensions: Height / Face 1 /Face 2 and two orientations of the stone). Completing this manually at a rate of two comparisons per minute it would take 325 working days to be completed.

3.4 Develop a software solution

Searching the internet for a suitable software application already in existence was unsuccessful. Many organisations had mapped and modeled existing facades, but none we could find had tried to match a pile of collapsed stones back to their original location. New software would have to be written using the macro language in Microsoft Excel.

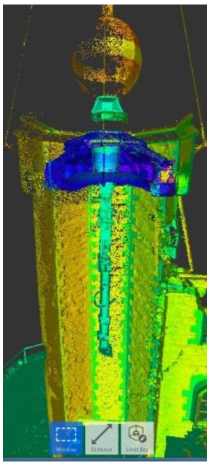
As the application developed over several weeks, new variables and potential combinations of stones became apparent. For each new function another unique case appeared which required the application to consider a new filter. It was known that every stone was from the tower, so the filter wasn't to ignore the problem but to find another solution to it.

One of the significant features of the application was the ability to set a confidence level for the measurements being applied. Recall that many stones were damaged and the original scan was of medium resolution, so accurate measurement was difficult to guarantee. The application first allowed measurements a tolerance of +-5mm, and then as more stones were located with high confidence, the allowable tolerance was gradually relaxed.

Ultimately, the tool takes a list of targets, a list of objects and a folder of images and by simply clicking a button returns a complete report ready for tender. 65% of the available stones have been matched to a position in six of the eight visible tower faces. Approximately 100 stones could not be matched to a location, so it is reasonable to expect that these stones are from the two obscured faces of the tower. When additional stones were later found in storage, the program was able to place them in the tower and provide an updated answer in a few seconds.

3.5 Model the mechanism – the image that saved the ball.

The tower without the ball and internal mechanism would not be a complete rebuild. But original as-built documentation didn't exist so there was no clear detail of the mechanism and what did exist were only old paper sketches. Nothing accurate could be found. A project was started to virtually reconstruct the mechanism in a digital space.



The first step was to scan the remaining foundation in terms of Lyttelton height datum and a known coordinate system. The point cloud from February 2011 could then be positioned on its virtual foundation and correctly coordinated. This task was complex as during the 2011 scan a large amount of stone piled on the ground hid the actual remaining ruin and only minimal data overlap was available. With careful effort, a satisfactory result was achieved and the virtual reconstruction could continue.

The architect, Dave Pearson Architects, tasked with creating the Revit model of the tower needed more information about the height of each element of the mechanism above the ground floor. The solution was to scan each piece of the mechanism as it lay in storage to obtain accurate measurements.

Work started with the stone tower dome which was well conserved and only partially damaged. Clear paint marks showed exactly where the mast fitted to it. Subsequently the two parts of the broken mast held in storage were scanned. Virtual reconstruction allowed us to move the pieces of this very heavy mast, one square and one round, with only the click of a mouse. The central axis of each piece was modeled and using matching connection points the mechanism was brought together in a digital space.

Together perhaps, but the precise location and level of the mast in the tower was still unknown. Only the internal structure of the dome and the mechanism were available and the February 2011 scan shows only the exterior of the building. There was no way to relate the two together. Completion of the project was close, but this important information for the architect and the rebuild was missing.

During one final meeting new images became available. One was a picture after the June 2011 earthquake where the building appeared no more than a mountain of debris with the dome on top. This critical image included a view of the exterior of the dome, with one broken stone that allowed visibility to a piece of metal which held the internal structure. This unique image provided the key to link exterior and interior scans together and completed the project to virtually rebuild the Lyttelton Timeball Station. Now the hard work of the real reconstruction can begin…

4. CONCLUSION

The work that Beca surveyors undertake often requires us to apply geospatial expertise to applications that go beyond the typical realm of the surveyor. However it is not often that a project emerges that offers opportunities as truly unique as the Lyttelton Timeball Station project for Heritage New Zealand. The combination of technical challenges and the status of the project as a landmark heritage restoration have been inspirational for the author and the outcomes have certainly justified the effort.

REFERENCES

http://www.heritage.org.nz/places/places-to-visit/canterbury-region/lyttelton-timeball

BIOGRAPHICAL NOTES

Guillaume CLIN has 5 years international professional experience in the widest range of precision surveying applications, including laser scanning, photogrammetry, settlement monitoring, topographic and engineering surveying. Guillaume enjoys the challenge of developing technical solutions for a successful outcome. He has a keen interest in new technologies and is continually assessing their use for ways to improve work processes that will provide efficiencies and add value to the client.

Richard HARRISON is a professional land surveyor with deep technical knowledge of GNSS, optical and laser-based measurement and positioning technologies, as they relate to Surveying, Monitoring, Civil Construction, Architecture and GIS. Richard has applied his knowledge and experience to a cross-section of practical surveying applications around the world, delivery of technical support and professional training to surveyors and sales agents, management of surveyors & geospatial experts, and direct sales of equipment and software.

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