Coloured 3D point cloud of Cologne Cathedral's interior. © Heriot Watt University

THE POWER OF 3DOM

A PROJECT TO DOCUMENT IN 3D GERMANY'S MOST POPULAR TOURIST ATTRACTION FACED MULTIPLE CHALLENGES, INCLUDING SAFELY USING LIDAR IN A PUBLIC SPACE. SIMON KRESSER EXPLAINS HOW IT WAS ACHIEVED

Cologne Cathedral in Cologne, Germany, is an exceptional building, worthy of its UNESCO World Heritage Site status. Construction of the cathedral began back in 1248 and was eventually completed in 1880. At 157m in height, it was the tallest freestanding structure in the world from 1880 until 1884. The building has endured significant challenges over the centuries but contemporary issues include urban encroachment, regional seismic activity, air pollution, global warming and, of course, the impact of more than six million visitors per year.

The Cologne Cathedral documentation project is a collaboration between Heriot Watt University (Edinburgh, UK), Hochschule Fresenius Cologne, and the Metropolitankapitel der Hohen Domkirche Köln Dombauhütte. Under the technical direction of Heriot Watt University, the purpose of the documentation project was to provide the cathedral administration with an exceptionally precise 3D as-built record to assist in the ongoing conservation, condition assessment and management of the structure. The project also provided an exciting entrance opportunity into the world of 3D scanning for students of the Fresenius University of Applied Sciences, Cologne.

The site work began in May 2015 with the terrestrial scanning of the vast cathedral interior. Douglas Pritchard, associate professor at Heriot Watt University, who was in charge of scanning, was assisted by students of Hochschule Fresenius Cologne, the cathedral and Z+F specialists. The scanners were initially positioned at grade, then moved up to various points along the triforium, at the apex of the ribbed vaults, and the upper level loft. The exterior scanning also occurred at grade encircling the entire building, then at the 20m and 27m parapet levels, along the roof and at the crossing tower. Particular attention was paid to individually capturing the Cathedral's flying buttresses.

In addition to navigating through the swarm of tourists, the biggest challenge of the project was to capture the surface detail of the two enormous Cathedral towers, which mostly took place in August 2015. The scanner was positioned along the base of the towers at the 100m level, then hauled up to the 150m level. Similar to previous documentation projects, a rigid extension arm was used to position the scanner out from the face of the towers. The scanner was positioned vertically to capture the top sections of the towers, then inverted to provide a better view of the entirety of the cathedral roof. The dual-documentation capability allows the scanner to be positioned once and then remotely operated – a necessary requirement when extending the scanner outwards on a rig.

Two Z+F laser scanners were used in the course of the project – the Z+F Imager 5010C and 5010X. Both scanners have a maximum range of 187m, scan more than one million points per second, are equipped with a HDR camera and are classified as 'eye-safe' according to laser class one. They can therefore be used in public spaces without any restrictions, which was crucial for the project. Due to the scanners' outstanding distance and angular accuracy, they are highly suitable for challenging heritage projects.

Since it only had been released a couple months before the project began, the Z+F Imager 5010X was the centre of attention. This scanner is equipped with an integrated positioning system, with the localisation of the scanner used for targetless, automatic cloud-to-cloud registration on the fly. The scanner, as well as the new Z+F LaserControl Scout software, enable the so-called 'Blue Workflow', which enables the user to take care of all scanning and preprocessing tasks while still in the field, saving time, effort and money. Instead of returning to the office to start preprocessing – in some cases even with an incomplete dataset – users have full control over the entire project at all times and are able to check, register, preprocess data and, if necessary, intervene on-site right away.

The adaptability and flexibility of the Z+F equipment was highly beneficial. In areas where the lighting was poor, Z+F SmartLights were quickly attached to the scanners to illuminate dark surfaces. To provide as much dimensional coverage as possible, the scanners

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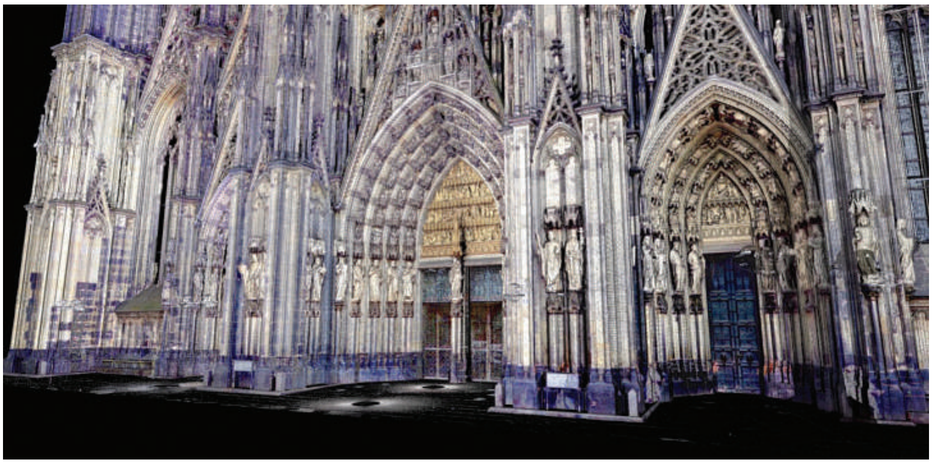

Coloured 3D point clouds of the Cathedral's main aisle. © Heriot Watt University

were occasionally inverted and lowered from the ceiling or suspended using a custom extension-rig, yet able to capture both scan data and imagery.

According to Douglas Pritchard, "to address the extraordinary size and scale of the building, considerable effort was made to push the capabilities and positioning of the scanner. In one situation, the 5010C was inverted, and carefully lowered through the keystone. In another, a custom extension rig was used to extend an inverted scanner off the face of towers. The remote operation of the scanners worked perfectly and the acquired 3D data and associated imagery are exceptional."

Christoph Held, application engineer and market development at Z+F, adds: "The entire project was a great opportunity to put our equipment to the test in a very challenging environment – especially the targetless registration with our Z+F Imager 5010X and Z+F LaserControl Scout. We're very happy with how everything worked out and all project partners approved of our newest laser measurement technology. This is also a great encouragement for us to continue developing innovative solutions, which make laser scanning even easier and more efficient."

Deliverables

The justification behind comprehensively scanning the cathedral was to provide the cathedral with dimensional data will be used for both conservation and educational interpretation. Furthermore, the requirement for the high number of scans with generous overlap is an attempt to future-proof the data, having the 3D detail to address current maintenance issues, but also prepare for unexpected challenges in the years to come. Approximately 660 full-colour interior and exterior terrestrial scans were captured in the course of the two project phases. The speed and density of acquired data of the 5010C and 5010X are highly beneficial but one of the reasons why the systems are so well suited for challenging heritage projects such as Cologne Cathedral is the ability to have an integrated laser scanner and high-resolution HDR camera at the same nodal point.

The scans have now been fully-registered, connecting both the exterior and interior data. An exciting development is that the master 3D dataset now extends from the absolute lowest extent of the cathedral foundation all the way to the very top of the two towers.

The next stages of production include the creation of detailed 2D CAD and 3D BIM conservation documents. With the same scan data, photorealistic 3D models are also being developed using a combination of AutoDesk ReCAP, ThinkBox Sequoia meshing software and 3D Studio Max to create animation and interactive game engine presentations. The purpose is to visually explain the evolution of the construction and sophisticated engineering behind this great building.

According to Pritchard, "the local public and international media have shown tremendous interest in this project, either regarding the symbolic meaning the cathedral has for its locals or the genuine issue of heritage conservation to monitor and serve future restoration ambitions for experts around Germany and Europe."

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Simon Kresser works in the marketing department of Z+F (www.zofre.de)