To metoder for innsamling av terrestriske laserskandata: Rosslyn Chapel kasusstudie

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Lyn Wilson & al: Two Avenues for Terrestrial Laser Scan Data: The Rosslyn Chapel Case Study

KART OG PLAN, Vol. 72, pp. 314–319, P.O.B. 5003, NO-1432 Ås, ISSN 0047-3278

Constructed between 1440 and 1486, Rosslyn Chapel has had a difficult history. It has suffered vandalism and neglect during the Protestant Reformation, used as a stable for Oliver Cromwell's horses during the English Civil War, unsympathetically renovated during the 1800's and nearly blown-up by the suffragette movement in 1914. During the 1950's the Chapel has suffered a failing roof in combination with an unsympathetic application of a white cementitious paint to the interior – essentially locking in the moisture into the stone.

As part of an ongoing research partnership, Historic Scotland and Glasgow School of Art systematically digitally documented the interior and exterior of the building and grounds over a three-day period. The purpose of the project was to implement a full 3D terrestrial laser survey of the existing structure to document its current physical condition and to help guide ongoing conservation techniques. Of particular concern was the structural integrity of the main vault during the conservation of the existing roof. Fourteen cross-sections were cut through the point cloud data to determine the exact thickness of the vault.

As part of the presentation material for the new Chapel interpretive centre, the terrestrial scan data was used to generate a 3D model and subsequent 3-minute animation, depicting the evolution of the Chapel from its construction to the Protestant Reformation. In addition, close-range scanning systems were used to generate sub-millimetre scans.

Key words: Rosslyn Chapel, 3D skanning

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1. Introduction

Rosslyn Chapel stands in a serene location on the outskirts of Edinburgh, Scotland. Constructed between 1440 and 1486 and furnished with flying buttresses and ornate sculptural carvings covering virtually every surface, it is widely hailed as a medieval architectural masterpiece (Figures 1a and 1b). The Chapel has been the focal point of many religious and political events since its foundation, while being the subject of numerous myths and legends relating to the Knights Templar and Freemasonry.

In the 1950s, the Chapel suffered from an unsympathetic renovation of the roof using white cementitious paint on the interior, which locked moisture into the stonework, caused the roof to fail and accelerated decay of the carvings. A temporary steel and aluminium structure was erected over the Chapel in 1997 to protect the monument from rain and to allow the stone to slowly dry out. In 2009, an extensive conservation programme was embarked upon, which aimed to restore the Chapel to its former glory and saw the removal of the temporary protective roof in 2010.

As part of the conservation programme, Historic Scotland and Glasgow School of Art were requested to carry out a 3D survey of the Chapel and its surrounding environment in 2009. The aim of this survey was to thoroughly digitally document the Chapel's current physical condition, inform the ongoing conservation process and provide 3D content for interpretation.

1. Historic Scotland, Edinburgh, Scotland
2. Digital Design Studio, Glasgow School of Art and CyArk Europe, Glasgow, Scotland

Figure 1a. Rosslyn Chapel with exterior temporary metal roof structure in place from 1997–2010.

Figure 1b. Interior sculptural detail at Rosslyn Chapel.

2. Methodology

A joint team from Historic Scotland and Glasgow School of Art systematically digitally documented the interior and exterior of the building and grounds over a three-day period. A combination of terrestrial time-of-flight (Leica ScanStation 2) and phase-shift laser scanners (Leica HDS 6100) were used as appropriate: time-of-flight terrestrial laser scanners (TLS) to survey the exterior and environmental context, phase-shift TLS to survey the interior spaces and roof details. For scans on the roof itself, the phase-shift scanner was set in place and operated remotely via wi-fi (Figure 2). At least 30% overlap between adjacent scans was ensured. Individual scans were registered using both HDS targets and cloud-to-cloud feature recognition techniques. Interior and exterior scans were joined using targets. This resulted in a unified registration with a mean average error of ± 8mm. The total number of scan positions was 142 and the total number of survey points collected was in excess of 4 billion.

360° panoramic high resolution HDR photography was taken at all scan positions using a Nikon D3X set upon a Nodal Ninja mount, offset to the same height as the laser sensor. Additional texture photography was taken to provide further information for model textures.

In addition to the TLS survey, high-resolution sub-millimetre scanning of particular sculptures was undertaken to provide an un-

Figure 2. Positioning the phase-shift scanner on the roof of Rosslyn Chapel for control via wi-fi.

paralleled record of their surface geometry. Both an articulated arm scan system (Perceptron Romer v5) and a structured light scanner (Artec MHT) were used for this process.

Aligned and registered point clouds were taken into Innovmetic's Polyworks software package to produce a mesh. Hole-filling was carried out for subsequent modelling, but it was important for us to recognise areas which represented voids in the data: our scientific approach meant the survey should be as objective as possible and any intervention by the modeller was identified by a different colour in the mesh (Figure 3). The mesh was finally imported into Autodesk 3D Studio Max to produce photo-realistic models.

Figure 3. Mesh of Rosslyn Chapel, obtained from TLS survey. Purple areas indicate modeller intervention, as it was impossible to obtain scan data from these locations.

3. Results

3.1 Survey and Conservation

The 3D survey provided baseline information on the condition of the Chapel prior to the conservation programme. A monitoring programme has been established for particular exterior stone panels: re-scans will be carried out at two yearly intervals and compared against the baseline using Polyworks Inspect package. Any erosion to the stone surface will be quantified and passed to Historic Scotland's stone conservators to make an assessment on the course of action needed. Ortho-rectified point cloud elevations and plan views were also generated of the Chapel and its grounds (Figures 4 and 5).

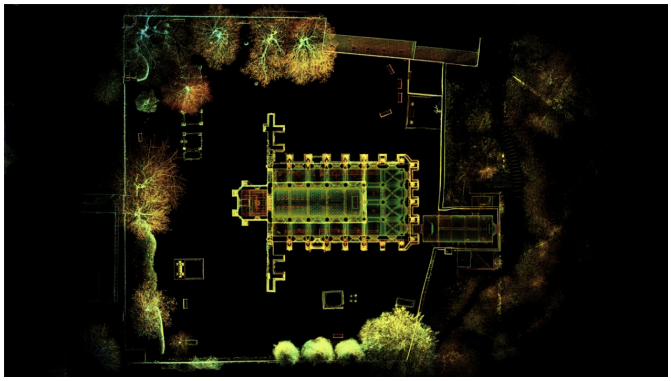

Figure 4. Point cloud plan view of Rosslyn Chapel and its grounds.

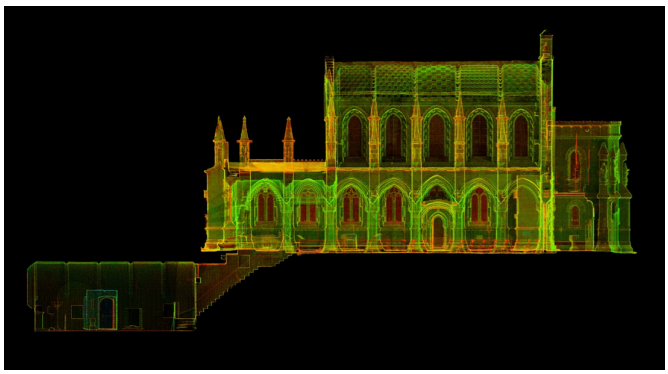

Figure 5. Ortho-rectified point cloud elevation of Rosslyn Chapel showing some internal structures and vaulted crypt.

Of particular concern was the structural integrity of the main vault during the conservation of the existing roof. Fourteen cross-sections were cut through the point cloud data to determine the exact thickness of the vault (Figure 6). This information allowed the on-site engineers and conservators to assess safe working practices for the duration of the project.

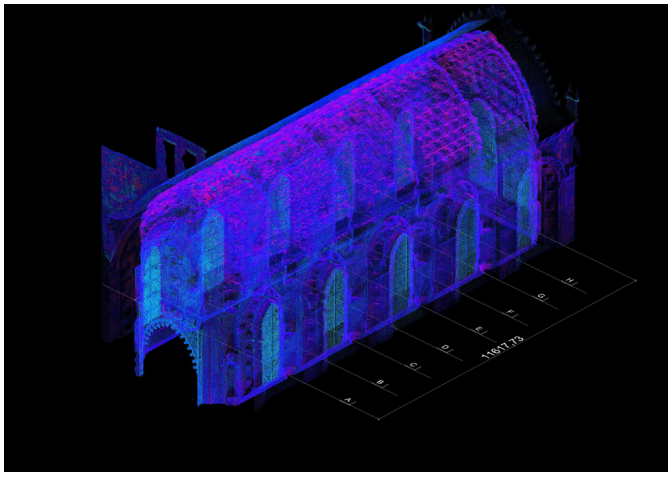

Figure 6. Image showing cross-sections cut through the point cloud to determine precise dimensions of vault.

3.2 Interpretation

As part of the presentation material for the new Chapel interpretive centre, the TLS data was used to generate a 3D model and subsequent 3-minute animation, depicting the evolution of the Chapel from its construction to the Protestant Reformation. In addition, close-range scanning systems were used to generate sub-millimetre scans of particular sculptures. The pagan 'Green Man' (Figure 7) and the 'Apprentice Column' were two of the sculptures digitally documented using laser and structured light scan systems.

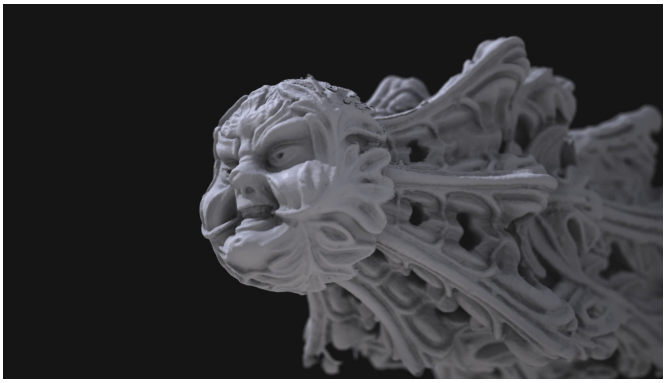

Figure 7. Meshed data from sub-millimetre laser scanning of the Green Man.

The point cloud data was developed into a mesh then a model, then animated in high definition at 25 frames per second to produce an interactive interpretive feature known as the 'Pathways to the Sculptures' (Figure 8). Several of these sculptures lie at inaccessible points within the Chapel. The interpretive content allows visitors to examine the sculptures virtually at close-range, without any risk to either the visitor or the sculpture itself. Combined with textual information on each sculpture, the 3D data is proving to be a valuable resource for explaining Rosslyn's sculptural legacy.

Figure 8. Beginning of 'Pathway to Sculptures' interpretive content for Rosslyn Chapel visitor centre.

Finally, an Apple iPad application is currently in development which will utilise the geometrically accurate point cloud information and the models derived from it to digitally showcase Rosslyn Chapel.

4. Conclusions

The digital 3D survey of Rosslyn Chapel has proven beneficial for two distinct avenues in addition to providing a highly accurate survey record. Tangible conservation applications and the generation of visually engaging interpretative materials emphasise the versatility of geometrically accurate point cloud data within the heritage sector. As Rosslyn Chapel's conservation programme continues, our 3D survey has also secured the digital preservation of this inspiring monument for future generations.

5. Acknowledgements

- All images are copyright of the Centre for Digital Documentation and Visualisation LLP.
- Rosslyn Chapel Trust: Colin Glynne-Percy
- Historic Scotland team: Maureen Young, Alan Simpson, James Hepher, Adam Frost.
- Glasgow School of Art team: Alastair Rawlinson, Craig Logan, Jared Benjamin.

Notis

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