IDENTIFICATION OF HISTORIC METHODS OF CONSTRUCTION USING DIGITAL PHOTOGRAMMETRY AND LASER SCANNING

M Murphy[a], Dr. E McGovern[a], R Olwill[a], Dr. S Pavia[b]
[a]Dublin Institute of Technology, Faculty of the Built Environment, Bolton Street, Dublin 1, Ireland,
maurice.murphy@dit.ie, eugene.mcgovern@dit.ie ,
[b]University of Dublin, Trinity College Dublin, College Green, Dublin 2, Ireland, Dr. Sara Pavia, pavias@tcd.ie

KEYWORDS: **historic construction techniques, laser scanning, digital photogrammetry, decay measurement**

ABSTRACT

In accordance with Article 2 of the Council of Europe Convention, for the Protection of the Architectural Heritage of Europe (Granada Convention), a National Inventory, a record of Architectural Heritage is now been undertaken by many countries in Europe. This coincides with new developments in surveying and recording techniques. This paper examines the application of automated surveying and recording techniques (integrating laser scanning, digital photogrammetry and CAD), through the recording of a case study of a 17th century streetscape based in the city of Dublin. The process results in the production not only of a record of the historic structure or artefact but also an analysis of historic construction methods, which may inform correct conservation of both structure and fabric. Automated recording and surveying techniques provide a digital image and vector record, facilitating analysis concerning many aspects of a historic structure or artefact. It is possible to abstract data relating to the original construction methods, materials and their sources and the monitoring/identification of damage and decay to objects or buildings. The paper is a collaboration of a multidisciplinary team from the Faculty of the Built Environment of the Dublin Institute of Technology and the School of Engineering Trinity College Dublin.

1. INTRODUCTION

The recording and documentation of historic structures can be greatly enhanced in terms of speed and accuracy of data collection using digital photogrammetry and laser scanning in comparison to traditional manual methods of survey. Laser scanning and photogrammetry records an object, but also supplies measurement data, texture, colour, and geometry, which define the object. Measurement data and geometry details from images can be plotted to scale and inserted into 3d and 2d CAD software programmes. Texture and colour data from the images will aid the identification of materials and damage/decay.

New heritage legislation and Government policy, in addition to an increase in conservation and repair of older buildings has created new requirements for protection of our Built Heritage. The recording and documentation of both historic structures and landscapes are the initial steps in compliance with both national legislation and international charters and guidelines. The process of conservation should also be the subject of recording as expressed in Article 16 of the Charter of Venice which states: "In all works of preservation, restoration or excavation there should always be precise documentation in the form of analytical and critical reports, illustrated with drawings and photographs. Every stage of the work of cleaning, consolidation, rearrangement and integration, as well as technical and formal features identified during the course of the work, should be included. This record should be placed in the archives of a public institution and made accessible to research workers (ICOMOS)."

In this paper, a case study based on the recording of 17th century Henrietta Street in Dublin, illustrates automated survey procedures for the collection, and dissemination of recorded historic architectural data. The study is limited to the recording and documentation of the external fabric of the street. Henrietta Street a Dublin Georgian streetscape is an ideal case study to illustrate architectural documentation and recording, because of its historic origins and its significant surviving architectural details.

This paper is divided into four sections:

1. Introduction
2. Laser Scanning
3. Survey of the Historic Streetscape
4. Analysing Historic methods of construction
5. Conclusion

2. LASER SCANNING

Laser scanning can replace existing methods used in "metric cultural heritage documentation" especially when large of amount of data have to be collected, as in the streetscape chosen for this study. The production of digital elevation models of buildings and land is a product of laser scanning enabling measurement and other data to be abstracted from the laser scan (Boehler et al 1997).

The laser scan will collect a large range of data representing three-dimensional co-ordinates, called "point cloud data" accompanied by proprietary software to manipulate massive amounts of 3D data. While laser scanners take a few minutes to scan millions of accurate 3D points, there is huge work in transporting this data into a 3D model containing useable information. The combination of digital photo modelling and laser scanning will enhance the point cloud data, combining the laser scans with digital photo modelling can further enhance the creation of realistic three-dimensional models from laser scans.

The 3D Terrestrial Laser Scanner used for the survey of Henrietta Street was the *RIEGL* LMS-Z420i a fully portable sensor designed for the rapid acquisition of high-quality three-dimensional images . The *RIEGL* LMS-Z360i provides a combination of wide field-of-view, high accuracy, and fast data acquisition. A standard Windows notebook and the software package RiSCAN PRO enable the user to instantly acquire high-quality 3D data in the field.

The main features of the *RIEGL* LMS-Z420i include:

- Range up to 200 m @ Laser Class 1
- Measurement accuracy up to 6 mm
- Measurement rate up to 12 000 pts / sec
- Field of View up to 90° x 360°
- TCP/IP data interface
- Operated by any standard PC or Notebook

Figure 1. *RIEGL* LMS-Z420i with a Nikon D100 camera used for the survey.

In addition to data, acquisition RiSCAN PRO software allows for other processing functions for the acquired scan data. This included the ability to generate meshes from the point clouds representing the scan data, to attribute colour information to every laser measurement, to generate undistorted and also merged high-resolution images for texturing the mesh, point cloud decimation, object construction from point clouds. The diagram below outlines part of this this process.

Figure 2. Above the point cloud with the associated image below it, the laser scan collects a large range of data representing three-dimensional co-ordinates, called "point cloud data". The combination of digital photography and laser scanning enhances the point cloud data, defining edges and texture.

3. SURVEY OF THE HISTORIC STREETSCAPE

3.1 Histories and Background: Henrietta Street

The beginning of Dublin's great building period can be traced to the early 18th century and to Henrietta Street. This street is considered one of the most important Georgian streets in both the UK and Ireland. Hence, its value to the city from both an architectural and historical perspective is immeasurable.
Development began on Henrietta Street by purchasing several strategic landholdings in and around the year 1714. Much of this land consisted of a large tract of what remained of St. Mary's Abbey. The first venture was Henrietta St. named after Henrietta the Duchess of Grafton. It was typically innovative. It was open to fields at one end and was intended as a prime aristocratic quarter. No. 9 was built by the Architect Lovett Pearse with No. 10 the developer's own home' (Olwill 2003).

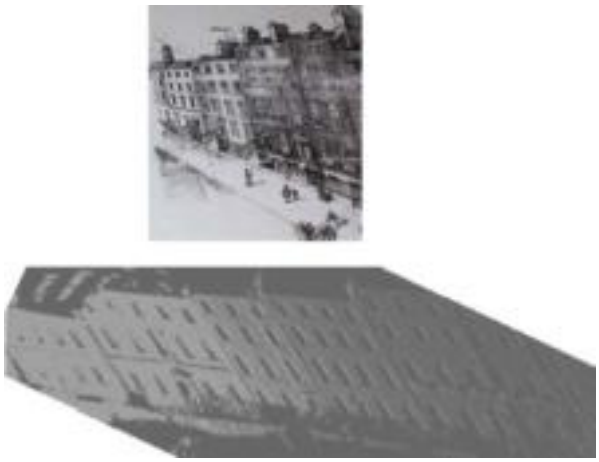

Figure 3. A drawing from the 18th century is compared with the recent point cloud scan, indicating that the street is still intact.

3.2 Streetscape

Henrietta Streets public domain gives the impression that the Street is 19th century in origin (whereas the first houses actually date from the early 18th century). This misleading impression is established by the Victorian style Street-lighting and the cobblestones.

3.2.1 Cole-hole Covers: Great varieties of circular coal plates with ornate patterns are to be found in the Georgian and Victorian streets of the inner city. They are mostly set in a granite slab where a hole was hammered out by hand to the dimension 300 mm to 355 mm in diameter into which was placed the coal plate 127 mm thick, in a variety of designs. Many of the early covers, cast in the 18th and early 19th century are badly worn but good examples are still to be found on Henrietta Street (O Connell D 2001).

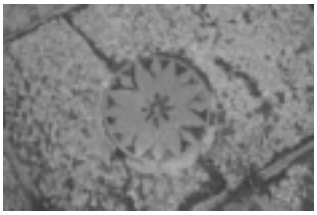

Figure 4. Cole hole covers

3.2.2 Iron Railings: Most of the iron used in Dublin during the 18th century was imported. During the first half of 18th century, the use of iron was limited to small items such as door furniture, coal and manhole covers, fire backs and railing posts.

Figure 5. CAD plot of railings from scan data

The demand for ornamental iron increased with the rise in the speculative building developments of the 18th century such as Henrietta Street. Whole terraces of Georgian houses were laid out with basement areas bounded by wrought iron railings (ibid).

3.2.3 Setts: Setts (Square block cobbles) developed from cobbles over a long period from the 16 th to the 19 th century. Henrietta Street would originally have been serviced by a dirt track with the setts most likely introduced in the late 19 th century (ibid).

Figure 6. Setts

4. ANALYSING HISTORIC METHODS OF CONSTRUCTION

4.1 External Elements and Building Facades

The main elements, which make up the facades of the houses on the street, are the brickwork in the external walls, the sliding sash windows, and the door-cases, doors and fanlights. Some of the original elements of the buildings are still in place and date back to the 1700s, or have evolved with additions over the centuries.

4.1.1 Brickwork: Brick and stone were the most common facing materials used in 18th Century Dublin, Henrietta Street is a typical example. The brick was in some cases imported from England, entering the country as ship ballast or came from Brickfields in Dublin or outside the city. Bonding refers to the pattern in which brickwork is laid; a Flemish Bond is used in Henrietta Street. The mortar joints are relatively wide because of the irregularity of hand made bricks. The mortar consists of a mix of lime and sand; to improve the appearance of the brick façade tuck-pointing was introduced in the 19th century (Keohane F 2001). The existing brickwork and mortar was painted and re-pointed creating an impression of a standard machine made brick and regular mortar joints. The original brickwork survives in numbers; 4, 5, 6, 7, 8, 13 and 14 Henrietta Street, whereas the reaming houses have most of their original brickwork with alterations. For example, tuck-pointing has been introduced to number 11 in the twentieth century. The window openings in most of the houses have been enlarged in the nineteenth century in some cases introducing changes to the arches over the openings (O Neill F 2003).

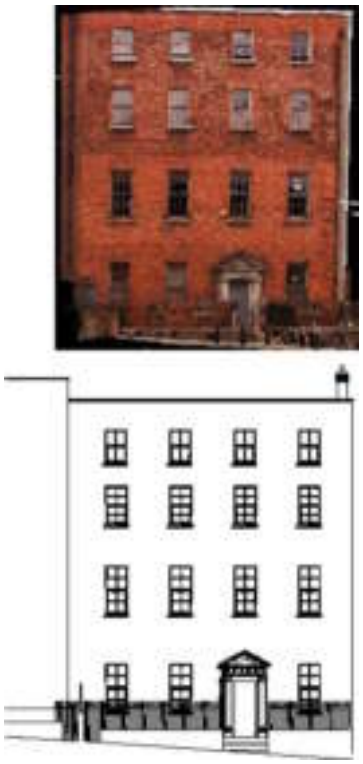

Figure 7. CAD plot from laser scan

4.1.2 Stonework: Limestone and granite are both found in the facades of the houses, calp a local limestone is used in the wall to some of the basements covered with a render, granite is used in plinths, cornices, steps, cills and copings. Imported Portland stone is used in the stone door cases; these are uniformly painted a creamy stone colour. This work carried out at a later stage, helps to disguise inferior materials and poorly matched stone, and protected the stone from direct weathering (ibid).

Figure 8. Image and point cloud of stone carving at bottom of street, the 3d point cloud is ideal for capturing sculpting and carving.

4.1.3 Sash Windows: The sliding sash window is the traditional window of most historic houses in Dublin. Changes in fashion led to windows being enlarged by dropping the cill level,

sometimes almost to the level of the floor. Numbers 4, 5/6, 7, 8 and 9 were all enlarged in the 19th century whereas, the original dimensions of the window openings still survive in number 15. Numbers 10, 11 and 12 contain remnants of alterations, which were made from the mid to late 1700s (O Neill F 2003).

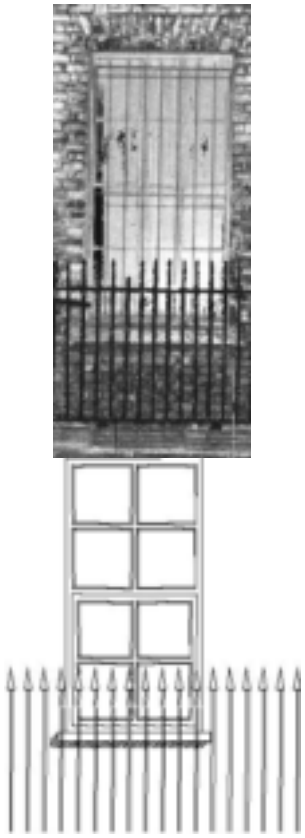

Figure 9. Sash window, CAD plot from point cloud

4.1.4 Doors , Door cases and Fanlights: Up until the late 17th century, most doors were constructed from vertical boards bound together on the inner side by horizontal timbers, known as ledges. From the late 17th century onwards, panelled door construction was introduced. From the early part of the 18th century, stone door cases in a classical style were used (Keohane F 2001). Constructed with pediments supported by columns, the door cases were further enriched with carved mouldings.

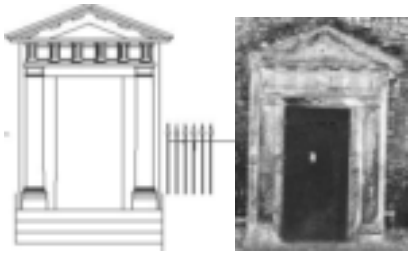

Figure 10. Door case plotted in CAD from point cloud

5. CONCLUSION - RETRIEVAL AND STORAGE

5.1 A digital database

A digital database is the final step, to integrate and make accessible to practitioners the recorded building techniques and the historic research information. The recorded data is in vector three-dimensional format and can therefore be placed within a GIS system. Retrieval of survey and historic data can be achieved through a mapping, interface whereby data is stored in a coordinate system (latitude/longitude, state plane, UTM, etc.). In the case of Henrietta street storage of all historical data and 3d and 2d scans of all the structures will be plotted on live vector maps and can be retrieved by the co-ordinates of the structures or other references.

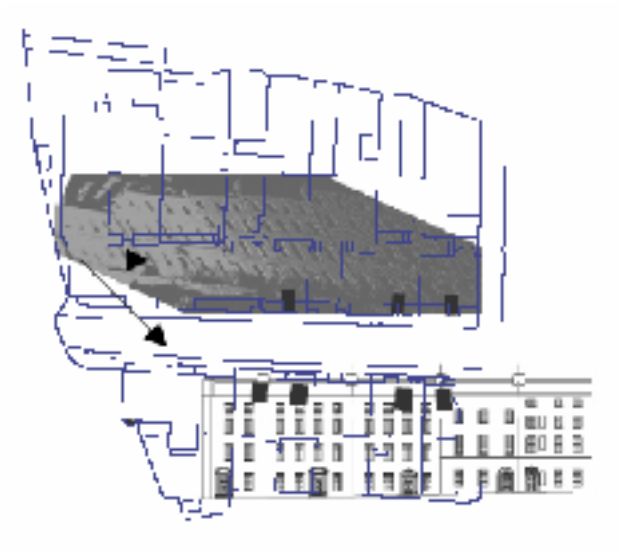

Figure 11. Map interface for retrieving survey data

REFERENCES

Boehler, W., Heinz, G., Marbs, A., The potential of non-contact close range Laser scanners for cultural heritage recording CIPA Working Group VI

CIPA International Symposium 1997, Goteborg, Sweden, ISPRS - International Archives of Photogrammetry and Remote Sensing, Volume XXXII, Part 5C1B

Keohane, Frank, Period Houses, A Conservation Guidance Manual, Dublin Civic Trust, 2001

O Connell Derry , The Antique Pavement, Unpublished Dublin Civic Trust, 2001

Olwill Ronan, Henrietta Street ACA, Dublin Institute of Technology, Planning Undergraduate Dissertation, 2003

O Neil Fearon, Structural Reports to Architectural Inventories, unpublished Dublin Civic Trust, 2003

Wehr A, Wiedemann A, Fusion of Photogrammetric and Laser Scanner Data, CIPA International Symposium 1999, October 3-6, 1999, Recife/Olinda - PE - Brazil

http://cipa.icomos.org/

http://hds.leica-geosystems.com

http://www.coe.int

http://www.icomos.org

http://www.riegl.com