

The Processing of Laser Scan Data for the Analysis of Historic Structures in Ireland

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Abstract

While laser scanners take a few minutes to scan millions of accurate 3D points, there is enormous work in transporting this data into a 3D model containing useable information. The testing and application of software platforms, which will manipulate the laser and image data, is necessary in order to identify the most efficient process for analysis of the laser survey data. The main aim of this paper is to present the findings to date of the processing of scan data of 17th and 18th century historic structures in Dublin. The process of reverse engineering is illustrated which generate orthographic plans, elevations and projections of the buildings to facilitate the analysis of the historic geometry, detail of building techniques and materials used.

Categories and Subject Descriptors J.6 COMPUTER-AIDED ENGINEERING Computer-aided design (CAD)

1. Introduction

Current research into automated recording and surveying techniques has been promoted by CIPA which is the International Scientific Committee for Documentation and Architectural Photogrammetry (CIPA) and is a joint committee set up by the International Council on Monuments and Sites (ICOMOS) and the International Society for Photogrammetry and Remote Sensing (ISPRS). The current research within CIPA promotes the development and application of laser scanning and digital photomodelling for recording architectural heritage, which is emerging as an innovative and novel solution for automating the process of surveying and recording large amounts of architectural data.

2. Processing Survey Data – Further Research Requirements

A laser scan collects a large range of data representing three-dimensional co-ordinates, called “point cloud data”; (see figure 1a) proprietary software is then required to manipulate massive amounts of 3D data. While laser scanners take a few minutes to scan millions of accurate 3D points, there is enormous work in transporting this data into a 3D model containing useable information. Dedicated software programmes such as polyworks, Leica cloud-works for AutoCAD and RiScanpro have greatly improved the processing, manipulation and analysis of vector and image data from the point cloud. All of these software platforms have combined algorithms for triangulation and surfacing of the point cloud [REM 2003]. Recent research for improving point cloud

data processing has been concerned with reducing the point cloud density without affecting the quality of geometric data and providing data management. High-resolution ortho- photographs when combined with the point cloud geometry comprise of more detailed image and geometric information than the conventional data sets of solely the point cloud. The recent developments of plug-ins for existing point cloud-processing software by SANDIG3D and CITY-GRID result in the creation of 3D models from the point cloud and associated image data in addition to the ability to create planes and sections for exporting to other programmes. This data is imported or exported across platforms in the following file formats: ASCII, XML, AutoCAD, 3D Studio or VRML. Recently the research work of English Heritage Metric Survey team and the University of Newcastle upon Tyne have produced a set of guidelines for the use of laser scanning in cultural heritage [BB 2005]. These guidelines establish the best practice for scanning cultural heritage objects for the production of an accurate record. Further research is required in the area of processing of scan and image data across a range of software platforms, to facilitate the identification and analysis of the historic techniques and materials used in the creation of the historic structures.

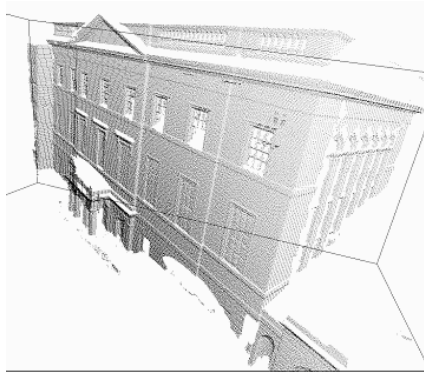


Figure 1:

- a. *Top -Example of Laser scan – point cloud of 18th Century Structure – Henrietta Street Dublin*
- b. *Bottom - Vector plot from Scan illustrating historic techniques used to establish façade.*

2.1 Data Collection

The following laser scan surveys were carried out in May and October 2006 using a Terrestrial Laser Scanner (RIEGL LMS-Z420i,) and were confined to the **front elevation façade and street fabric** of Henrietta Street and Capel Street 17th and 18th century Georgian streets in Dublin City. Data was collected using a terrestrial laser scanner combined with digital photo modelling. The terrestrial laser scanner consists of a laser ranger that is directed towards an object of interest by a dual-mirror system. The laser ranger measures distance, using the time-of-flight principle, based on diffuse reflection of a laser pulse from the surface of the object. The laser scanner is combined with a digital camera, which captures corresponding images to the scan, appropriate software is later used to combine the image and scan data. Digital photo modelling is used alongside the laser scanning, but can also be used for independent data collection where laser scanning is not appropriate. Digital photo modelling is the process of obtaining three-dimensional geometry

from a single or series of images. The recorded image of an object can be accompanied with measurements, which define a plane on this object [BHM 99]. Camera calibration is introduced to correct for the distortion of lenses, this image can then be correctly scaled to represent the geometry of the recorded object. Information concerning colour and texture of the object can also be provided.

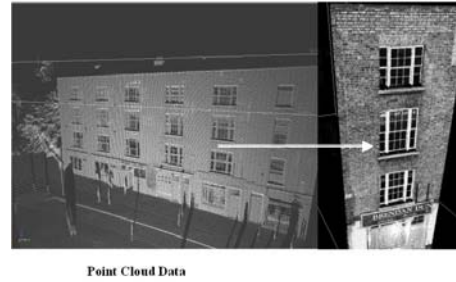


Figure 2: *Point Cloud of Capel Street 18th century Façade*

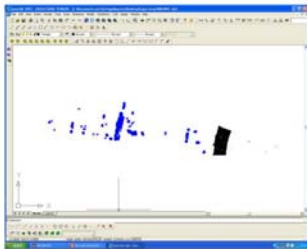
2.2 Processing

The initial data obtained from the laser scan surveys is described as a point cloud (see figure 2.). Thousands of points are recorded per second, at centimetric grid intervals, across a scanned object to build up a dense 3D-point cloud representation of the object containing, typically, millions of points and requiring specialist software to process. The three dimensional points are in a common co-ordinated system that represents the spatial distribution of an object or site. It can contain also the RGB values for each point. The point cloud density depends on the relative distance between co-ordinates. The point cloud can represent a single or a number of small or large objects or these objects can form a part or whole of a building or site.

The large amount of data, which represents three-dimensional coordinates of an object, must be processed in order to abstract geometry, shape, measurements, and texture. RISCAN PRO the companion software to RIEGL 3D Scanners (LMS-Z210i, LMS-Z360i, and LMS-Z420) is used as the platform to process the point cloud survey data. The point cloud can be used as a visualisation tool before processing. The scan can be coloured from the images taken from the same position as the laser scanner. A three-dimensional model used for visualisation is the initial product of the laser scan survey, which allows for full orientation and the creation of walkthroughs of the coloured point cloud.

2.3 Data Cleaning and Sorting

The first stage involves cleaning the data to remove artefacts such as reflections of the scan through objects. As stated previously the point cloud is made up of millions of points and is not suitable for plotting vector orthographical projections or for material analysis. It is not usually possible to export the point cloud into AutoCAD or similar programmes because of the size of the data set. If the density of the point cloud is reduced and the data is cleaned of unnecessary points the data can be imported into AutoCAD for plotting. RiCube is available as an additional software platform for RiScan Pro to process point cloud data, to improve the accuracy and to reduce the amount of data. The point density on the object surface varies significantly due to the varying range to the surface during acquisition. Processing using RiCube is based on sorting all data in an octree structure followed by cleaning and sorting of the data. The processed point cloud can be exported in various formats including 3PF, ASCII, Autodesk DXF, VTK, and WRL as reduced data sets for processing in programmes such as AutoCAD.



Clean scan in CAD

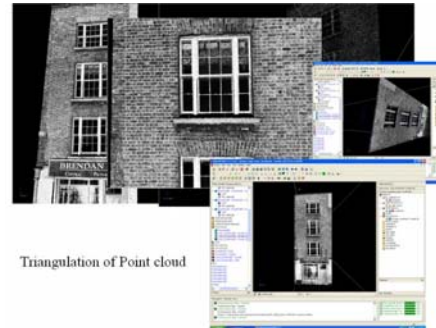
Figure3: *Cleaning Data Artefacts*

2.4 Meshing

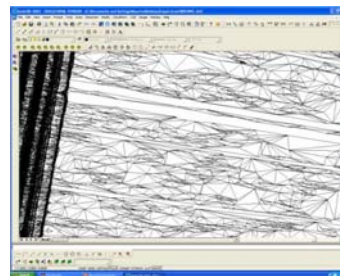
The point cloud data does not carry the image data when exported; therefore, edges and texture are missing when the data appears in AutoCAD or similar programmes. The creation of a three dimensional ortho-image allows for all of the image and geometric data to be exported for further processing. This involves processing the point cloud through the following stages triangulation, meshing and texturing with the corresponding position image data and combining the colour textured scan with the corresponding geometric plane of the associated scan image [NDS 2005]

Triangulation is the initial process (see figure 4), which creates a surface on a point cloud; the created surface is made up by triangles connecting the data points. A 2D-Delaunay triangulation algorithm is used to triangulate the data. The Delaunay triangulation is computed from the 2D coordinates of the points mapped onto the computer screen. Triangulated data (also called "mesh") improves definition of the scanned object, (de-

fining objects, edges etc.). The function of smoothing modifies the surface structure of the polydata object by optimising the point data; decimation is a process to reduce the amount of polygons and points in the mesh (see figure 5).

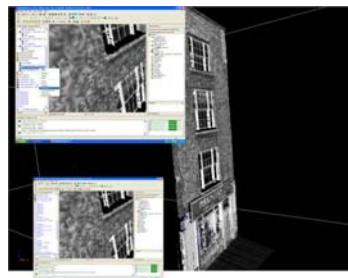


Triangulation of Point cloud



Triangulated point cloud in CAD

Figure 4: *Triangulation of Point Cloud*



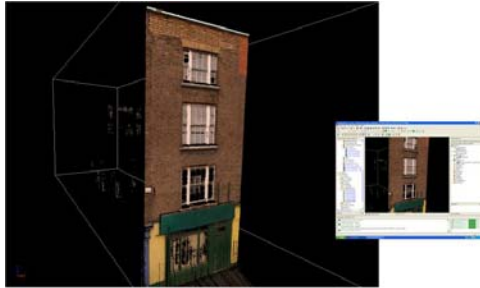
Smoothing and Decimation

Figure 5: *Smoothing and Decimation*

2.5 Texturing

Additionally triangulated data can be textured (see figure 6) with the high-resolution images taken by the digital camera which leads to a nearly photo realistic model.

The texturing procedure takes every triangle and tries to find the optimal image to texture it. The image has to meet several criteria such as smallest distance between camera position and centre of a triangle, visibility of the triangle in the image (no other objects between camera position and triangle) and smallest angle of view. Different parts of the point cloud are triangulated until the desired result is reached.

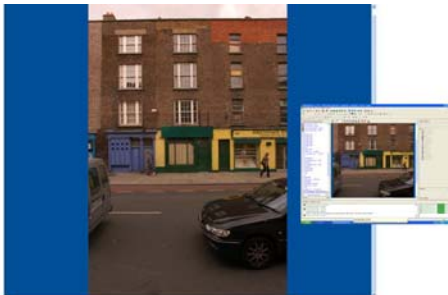


Texturing from image

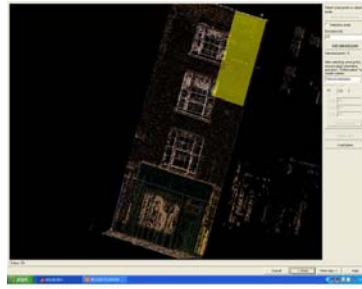
Figure 6: *Texturing of point cloud from image*

2.6 Ortho-Image

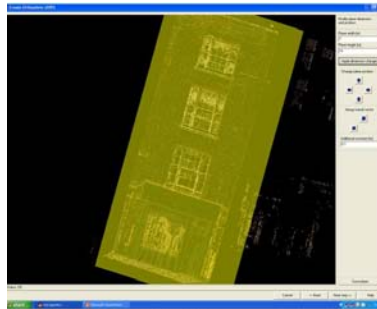
The generation of the ortho-photo is based on the geometry information (scan data) and image data. Images taken by the camera can be distorted by the lens and must be rectified during the processing stage. The ortho-photo represents the data for a particular plane on the x, y, and z-axis; this can therefore represent elevation, plan, or section of an object [RIS 2006]. The planes can be created on the x-y, x-z and y-z axis.



Un-distorting image



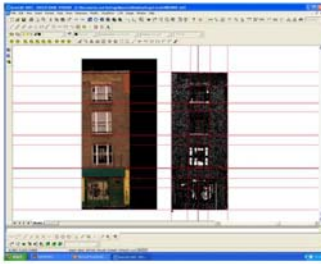
Create plane for ortho image



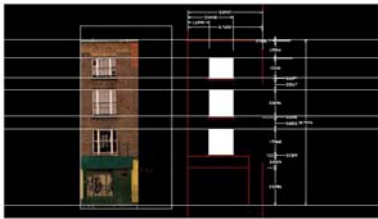
Position plane for ortho image

Figure 7: *Processing of image and textured point cloud data to create ortho-image*

Near and far planes are established parallel to the projection plane (distances along the normal vector of the projection plane) between the projection plane and the near plane and the projection plane and the far plane.



Plot from point cloud and ortho image



Plot from point cloud and ortho image



Plot from point cloud and ortho image

Figure 8: Plotting of vectors from exported point cloud and ortho-image in AutoCAD

2.7 Reverse Engineering

The final process of reverse engineering is illustrated in figure 8 above, the production of orthographic plans, elevations and projections of the buildings to facilitate the analysis of the historic geometry, detail of building techniques and materials used.

2.8 Conclusion

The following is a summary of the main process stages; initially the point cloud is triangulated and meshed, texturing the triangulated data with colour information from the high-resolution images then follows this. Defining vertical and horizontal planes on the textured scan to match image geometry is then

followed by the creation of the orthographic-image; this is a combination of the geometry of the point cloud and the colour and texture from the image. The elevation of the street facades can then be plotted using the point cloud and ortho-image in AutoCAD. The vector plot in figure 9 below was constructed using the above processPDF Generation.

References

[REM 2003] REMONDINO FABIO, *From point cloud to surface: The modeling and visualization problem*, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV-5/w10. International Workshop on Visualization and Animation of Reality-based 3d models, 24-28 February 2003, Tarasp-Vulpera, Switzerland.

[BMB 2005] BARBER D, MILLS J, BRYAN P *Towards a standard specification for terrestrial laser scanning of cultural heritage*, School of Civil Engineering and Geosciences, University of Newcastle upon Tyne, Newcastle upon Tyne and English Heritage Metric Survey Team, English Heritage, , 2005, York.

[BHM 99] Boehler, W., HEINZ, G., MARBS, A., 1999, Documentation - Surveying - Photogrammetry, W. Boehler, G. Heinz CIPA International Symposium, October 3-6, 1999, Recife/Olinda - PE - Brazil

[NDS 2005]W. NEUBAUER, M. DONEUSB , N. STUDNICKA, J. RIEGL, Combined high resolution laser scanning and photogrammetrical documentation of the pyramids at Giza, CIPA 2005 XX International Symposium, 26 September – 01 October, 2005, Torino, Italy.

[RIS 2006] RiScan Pro, 2006, Operating and Processing Software, Riegl, Austria, <http://www.riegl.com/index.htm>