MAINTAINING MOMENTUM IN TERRESTRIAL LASER SCANNING: A UK CASE STUDY

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KEYWORDS: Archiving, Cultural Heritage, Management, Laser scanning, Point Cloud, Specifications, Standards, TLS

ABSTRACT

Terrestrial laser scanning has been rapidly adopted around the world as a tool for capturing three-dimensional survey data in a variety of applications. This rapid take up continues, but clients, and therefore data providers, are becoming increasingly interested in ensuring that data is fit for purpose and provides value for money. Specific professional guidance is required in response to this need and in providing such advice it is important to consider the current state and future direction of the sector in question. Also, the mechanisms used to develop and disseminate guidance are as important as the advice itself, ensuring it is considered as impartial by its end users. This paper summarises these issues and provides a case study in the form of an ongoing UK project that is developing professional guidance for the application of terrestrial laser scanning in the recording of cultural heritage. As part of this project the issue of data formats for terrestrial laser scanning has been considered. Several recommendations are provided here to encourage the adoption of a common terrestrial laser scanning data format for the exchange, management and archiving of point cloud data. Such a development would have an impact on many of the applications now routinely using laser scanning.

1. NEW TECHNIQUES, NEW RESPONSIBILITIES

1.1 Introduction

Film sets, forests, construction sites, industrial plants, road accidents and prehistoric art are just some of the subjects now benefiting from the use of terrestrial laser scanning (TLS). An increasing number of users are being able to improve decision making processes by reducing the cost and increasing the speed of measurement tasks, or by being able to undertake jobs that before the advent of TLS were difficult or even impossible. The use of any new technology does not, however, remove the need for professional accountability; instead it places new responsibilities on the surveyor.

To date, little or no work has been done on the provision of professional guidance to the users of TLS (see Barber et al., 2003; Bryan et al., 2004 for examples). Partly due to the lack of such guidance, it is common to see commercial operators investing heavily in training and the development of processing flow-lines, alongside the purchasing of TLS equipment and software. In parallel with this formal activity come the lessons learned from trial and error. However, this commercially focused activity is generally intended to provide a competitive advantage over other operators and is not generally available as guidance for a sector as a whole.

The TLS sector in the UK is steadily growing, especially as TLS is one of the first measurement techniques to have been widely embraced by users outside geomatics. The obvious reasons for this are its instant visual appeal (especially to users who are becoming increasingly au fait with three-dimensional computer visualisation techniques), the perceived speed of data capture and the simple black box design of most systems (especially in comparison with techniques such as photogrammetry). These new users, not necessarily experienced in measurement procedures but anxious to make TLS pay in projects, have resulted in a growing need for education and training. This need is increasingly met by manufacturers who, with the ability to provide one-to-one tuition and access to equipment, are increasingly influencing how TLS is used. In order to maintain the momentum of TLS it is necessary to ensure that independent guidance, providing appropriate recommendations, is available as for other techniques (Bryan et al., 2000).

1.2 Standard practices

Without standard practices a client will find it difficult to ensure fitness for purpose and to validate the quality of a delivered product. It would also be difficult to archive survey data and ensure it could be reused at a later date, thereby decreasing its value. A lack of standard practices would result in an increase in training requirements for new staff and would make it more difficult to take advantage of technological improvements. Even if standard practice exists amongst users of the same manufacturer, incorporating data from other manufacturers would still be difficult. Standard practices improve efficiency and provide confidence in a technique, thereby providing a foundation for the ongoing development of technology and products/services.

1.3 New services

The introduction of TLS has made the provision of detailed three-dimensional spatial information much easier. Although ongoing development of instrumentation is inevitable, it is the tools required to serve and integrate this data with existing processes that are becoming the main focus. One future commercial development is likely to be a move towards providing managed/serviced products, rather than on-demand maps and plans. Managers, from a variety of sectors, may start to look towards the maintenance of full three-dimensional records of their sites/facilities that are updated at regular temporal intervals. This could apply to historic buildings where erosion/deformation needs to be monitored or to a civil engineering site where measurement and recording is required after each stage of construction. Thus the deliverable from the surveyor could become a service-based product rather than a one off commission, improving management of the facility and potentially providing new commercial services for operators to offer. For such services to be feasible, standard practice and guidance will be vital.

2. PROVIDING GUIDANCE

2.1 Audience

For guidance to be useful it must be provided at a practical level. In order to achieve this it must consider the needs of different audiences.

- The first and most important audience are the users of the products since they drive the need for TLS. Users have a responsibility to specify the right product for the task in hand and to allow that product to be generated as cost efficiently as possible. Generally, guidance to users within a specific discipline should be provided at a non-technical level using examples and case studies where possible. Explanation should be provided where required, thereby ensuring understanding rather than the blind application of the guidelines.
- The second audience is the providers of survey products. Providers require technical guidance that helps them to select appropriate parameters and techniques that fulfil client requirements. Having formal guidelines helps to justify these choices to a client, improving confidence in a provider's ability to provide an appropriate and accurate product.
- The third audience are the instrument manufacturers and software developers. Manufacturers respond to client needs and helping a manufacturer to better understand these requirements increases the chance of developing effective solutions to problem areas. Clear guidance could, therefore, have a direct affect on the development of TLS.

Although providing guidance to just one of these groups would lead to benefits, it is unlikely to be universally recognised. Therefore, the process of developing guidance should use a cross-audience approach, for example by bringing together different manufacturers and vendors. Finally, although guidance is generally provided in a discipline specific manner, a wider audience should be addressed by placing the guidance in a wider context, ensuring the demand for TLS is maintained and development driven across a number of sectors.

2.2 Mechanisms

The mechanisms used to develop guidance are an important factor in bringing together these audiences. A range of activities must be used to ensure input from all interested groups. Technical meetings may be used to establish detailed scientific specifications, while more general brainstorming sessions may be used to consider the general requirements of the users. Guidance must also be accessible, provided in a clear and unambiguous form and be widely advertised/marketed. It must provide adequate technical details in addition to practical advice.

Although the internet now provides excellent dissemination opportunities, it cannot replace the need for human interaction in developing the guidance. The act of facilitating such activity will often also lead to numerous benefits, such as improving networks of users and providers.

In order to demonstrate one approach in developing and providing guidance to a specific sector, this paper will describe an English Heritage funded initiative based at the University of Newcastle upon Tyne, UK. This will lead onto the discussion of point cloud data formats, an issue identified as part of this project that has wider implications to all users of laser scanning. This issue will be discussed, a brief background given and recommendations provided.

3. CASE STUDY: HERITAGE3D

3.1 Aims and objectives

The Heritage3D project directly addresses four sections of the 1998 Exploring our Past Implementation plan (English Heritage, 1999). Running for 24 months from September 2004 it is developing and supporting best practice in terrestrial and airborne laser scanning for archaeology and architecture, and disseminating this best practice to users and providing education of the likely beneficiaries. In order to achieve these aims the project works towards five objectives using a number of different mechanisms. These are:

- the production of a guidance note that demonstrates the type of products that can be generated from laser scanning;
- the updating of the current Addendum to the Metric Survey Specification to take into account the continuing advances in the technology (Barber et al., 2003; Bryan et al., 2004);
- to increase the knowledge base of English Heritage by forming partnerships with external survey practitioners/equipment manufacturers within the UK;
- to promote synthesis between disciplines within English Heritage by publishing and maintaining a project website;
- to provide workshops on the use of laser scanning to educate archaeologists, architects and engineers from within English Heritage and the heritage community in general.

3.2 Web based dissemination

The project's central dissemination hub is through the www.heritage3d.org website (Figure 1). This provides access to activity reports, case studies and draft guidance

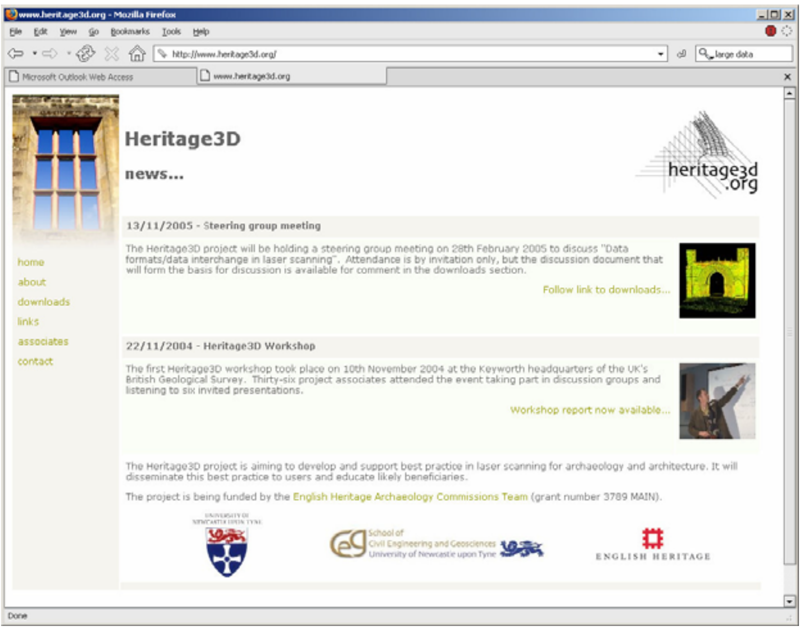

Figure 1 The Heritage3D home page

notes. It also provides links to other useful relevant websites, in addition to recognising the efforts and inputs of the project associates.

3.3 Project associates

"Project Associate" is the status afforded to the network of experts, users, developers and manufacturers that have been built to guide and support the project. By building such a network and knowing the skills, interest and experience of each associate, it is possible to direct questions, requests for review and participation in steering groups to specific individuals with a guaranteed response. Currently the project has over 60 project associates, acknowledged at the end of this paper.

3.4 Site/workplace visits

In order to allow for one-to-one discussions with users and providers, a number of targeted visits have been carried out to their workplaces. Unlike steering groups these visits are aimed at sampling current practice in processing, presenting and managing scan data. The results of each of these visits are available through the project website.

3.5 Steering groups

Small, specialist panels are used to review guidance and to discuss specific issues that are too specialised for discussion at larger workshops. Typically these steering groups last half to one day and involve up to 8 project associates and project staff. At the time of writing a steering group has been used to discuss issues relating to data formats (discussed in full in Section 4), with the results of each steering group also available from the project website.

3.6 Workshops

Two workshops are to be held during the life of the project. The first was held in November 2004, preceding a two day symposium on laser scanning held by the UK's Remote Sensing and Photogrammetry Society (RSPSoc). The presentations given at the workshop and a report of the meeting can be found in the download section of the project website. In summary the first workshop brought together over 30 academic and commercial users, developers and data providers of laser scanning in the heritage sector and beyond. Through a mixture of six invited presentation and small discussion groups a number of the salient issues facing the application of laser scanning to heritage subjects were identified. These discussions allowed the major technical priorities of the project to be prioritised.

One of the areas identified from the initial workshop as a high priority was guidance on the measures of quality necessary to allow impartial assessment of geometric/content accuracy. This is seen as vital in the assessment of data's 'fitness for purpose' and in ensuring contractual obligations are fulfilled during data collection. Intertwined with this topic is the choice of final deliverable and the processes used to create it. The requirements of the end user obviously plays a key part in this, as users are unlikely to require only the basic point cloud, that may be collected by laser scanning. Guidance to define pertinent standard deliverables was also seen as an important requirement.

The most important requirement for ensuring successful archiving is forward planning (Hardman, 2004). Being able to plan for data reuse ensures that best value is achieved from laser scan data. The relatively small range of affordable software tools available for the use of laser scanning data in heritage applications currently limits the data reuse capability. For example, while many users can access digital imagery or drawings, relatively few can currently easily access scan data or its derived products. This is often due to the size of current and future scanning projects (Carty, 2004). Key guidance is required on the most appropriate software systems to purchase and data formats to use.

Laser scanning often needs to be augmented by other survey techniques. For example, while scanning has generally proven to be an excellent technique for recording surfaces (providing an appropriate sampling resolution is selected) techniques such as photogrammetry are more suited to the recording of distinct edges (Boehler, 2004). Scanning may also be usefully used with other, non-measurement, techniques such as advanced computer rendering techniques (Gillibrand, 2004) to assess the impact of lighting and orientation.

A two day workshop is planned towards the end of the project in mid-2006. Details of this will be found on the project website in due course.

4. POINT CLOUD DATA FORMATS

4.1 Introduction

One of the major topics identified by the November 2004 workshop was the archiving of data products derived from scanning. No standard data format exists for the archiving of point cloud datasets from TLS. This topic was discussed in more detail at a steering group meeting in February 2005. Although this discussion was related specifically to heritage applications the outcomes repeated here are considered to be generic to all users of TLS.

It was recognised that a common data format allows:

- archaeology, architectural and other types of data to be archived effectively, thereby ensuring a primary data record of the subject;
- efficient and recognised data exchange between contractors, clients and users;
- software to be selected based on its ability to process data, rather than ability to import specific formats.

4.2 Data products

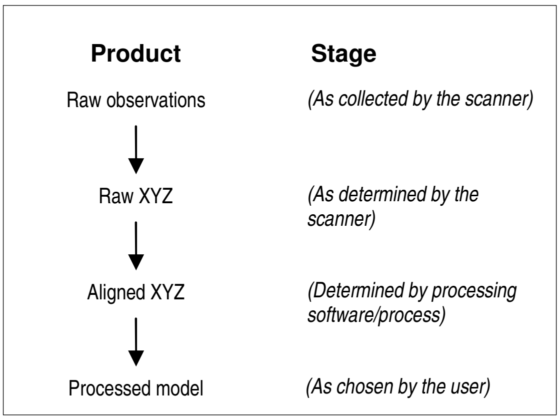

Figure 2 Data products at each stage of the scanning flowline

There are a number of opportunities throughout the scanning flowline for archiving the generated data products. Terminology for the different data products available is provided in Figure 2**Error! Reference source not found.**. 'Raw observations' are clearly the most preferable data product for reprocessing, which may include tasks such as the re-alignment of point clouds. However, it is almost impossible to place raw observations in a common format, given that each scanning system produces data using different models and/or principles. Instead it is likely that in future, service providers might keep the raw observations in a propriety format and export raw XYZ data from the scanning system.

Analysis of this flowline helps to aid understanding of how data is used/stored at different levels. The end user is likely to be concerned only with the format of the processed model. This model is likely to be the basis for their interpretation and decision making (the task for which all survey data is eventually applied). This product should itself be archived in some useable format but as it is likely to be based only on the collected scan data (a point cloud) it will not retain all of the original data. For example, in some applications CAD primitives may have been used to turn a set of 1000 points into a single four parameter plane, or a meshed model based on the entire dataset may have been decimated to produce a model useable on a desktop PC. Thus, without retaining the original Raw or Aligned XYZ data products new processing, perhaps to validate the processed model at a later date or to generate a new type of processed model altogether, will not be possible. Thus the user should be ensuring value for money by requesting the original data, in a generically useable format, in addition to the processed model. Although such a format might be used for both archiving and processing stages this requires a difficult compromise as processing tends to require more information than just vertex coordinates, such as topology or normal information. It would be more straightforward to use a format to simply deliver Raw XYZ or Aligned XYZ from which further processing, in any software package, can take place.

4.3 Format ownership

Proprietary data formats belong to a manufacturer who maintains the data format for use in their own software. Some commercial formats, such as the Drawing Exchange Format (DXF) (AutoDesk, 2005) have become standards in their own right, and are available for implementation in other systems. Other data formats are open source, intended to ease the transfer of data between users without the conflict of interest offered by a commercial format. Open source formats make it more likely that data remains accessible in the future, so long as records of a particular data format specification are maintained. Many data formats are designed to be extended to allow development of a format as necessary when new sensors, parameters need to be stored.

4.4 Delivery standards and data formats

An important distinction can be made between a delivery standard and a data format. A delivery standard outlines how disparate data is related and packaged to provide an entire dataset, perhaps the data archive for a particular survey. An outline of a delivery standard is provided in Figure 3**Error! Reference source not found.**. A detailed discussion of delivery standards is not within the scope of this discussion, except to highlight the role of the data format (of any type) within it (such as the examples in green) and the need for detailed metadata. The possible content of a Point Cloud data format is highlighted in yellow, while supporting metadata information would be contained separately for each data type (shown in blue). A delivery standard is an important tool in managing large, multi-source datasets about a particular site or subject, although it requires suitable tools to be made available.

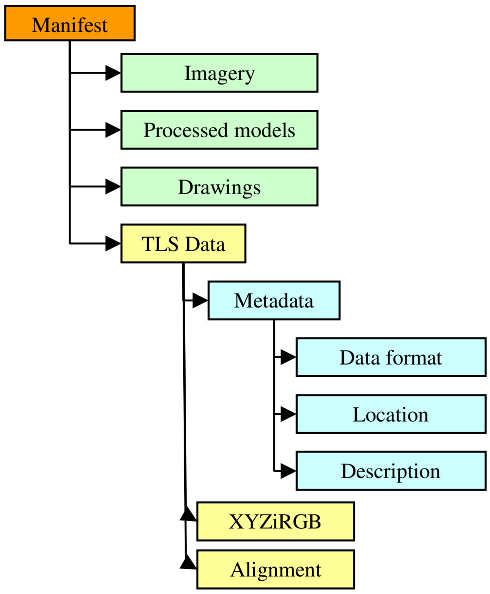

Figure 3 A simple delivery standard for survey data, including TLS data

4.5 The LAS format

The LAS file format is a public file format for the interchange of Airborne LIDAR data between vendors and customers. It is a binary file format alternative to proprietary systems or generic ASCII files. There are two major problems with ASCII file interchange. Firstly, file sizes can be very large and when using ASCII files the interpretation of data can be very slow as a consequence. Secondly, and more seriously, all information specific to LIDAR data can be lost. The LAS file format is a binary file format that maintains information specific to the nature of the data while not being overly complex (LAS, 2003).

Importantly the LAS format allows for user extension of the format by the addition of variable length records and user defined point data record formats. A public header block provides general information on the system used to capture the data, the date collected, minimum and maximum values and the number of records. Variable length records then allow a data provider to insert their own record, this includes specifying the point data record format. This too is user definable, although it is left for the owner of the record format to publicise this (keys for adding variable length records and new point formats are distributed by the LAS format committee of the ASPRS).

The Heritage3D steering group sees the use of the LAS format as the obvious choice for the delivery and archiving of airborne LiDAR datasets. Given the likely future integration of terrestrial and airborne datasets, use of the LAS format for the exchange of TLS data products also seems sensible. However, in its present form it does not easily lend itself to the storage of terrestrial datasets. However, the public ownership, support (approved by the ASPRS in 2003) and potential flexibility of the LAS format make it an attractive solution for the generic storage of TLS point cloud datasets.

4.6 Proposed changes to existing LAS

It is proposed to extend the LAS format to make it suitable for the storage of terrestrial datasets. This is recommended to be on a one-scan per-file basis. The amended format would be suitable for storing raw and aligned XYZ data. Although small, the proposed additions would be significant in promoting the use of terrestrial datasets to a number of applications.

4.6.1 Range grid structure

TLS data is generally collected in a range grid structure, for instance using a row/column approach. Therefore, support for range grids is required with the addition of a yes/no flag along with the dimensions of the range grid. The use of a range grid structure has benefits to the compression of data volumes. In order to allow this a new point data record format will be required. Importantly zero range records will need to be recorded to preserve the range grid structure. These records will be easily compressed by compression algorithms such as GZIP.

4.6.2 Alignment and transformation information

Provision is required for storing alignment information for TLS data. This is most usefully presented as a 3 x 3 transformation matrix although, given the opportunity for slightly different implementations of rotations matrices, it is important to explicitly identify the matrix elements. The adopted matrix should follow the proposed ISO recognised standard for R_{11} to R_{33} (row/column) given in the draft ISO/TC 210 Geographic Information/Geomatics specification (ISO, 2005) where:

$R_{11} = \cos\varphi * \cos\kappa$

$R_{12} = -\cos\varphi * \sin\kappa$

$R_{13} = \sin\varphi$

$R_{21} = \cos\omega * \sin\kappa + \sin\omega * \sin\varphi * \cos\kappa$

$R_{22} = \cos\omega * \cos\kappa - \sin\omega * \sin\varphi * \sin\kappa$

$R_{23} = -\sin\omega * \cos\varphi$

$R_{31} = \sin\omega * \sin\kappa - \cos\omega * \sin\varphi * \cos\kappa$

$R_{32} = \sin\omega * \cos\kappa + \cos\omega * \sin\varphi * \sin\kappa$

$R_{33} = \cos\omega * \cos\varphi$

4.6.3 Support for RGB/image information

For an increasing number of terrestrial datasets, imagery is becoming a key information source alongside the geometric information collected by the scanner. It is increasingly necessary, therefore, to provide the opportunity to store RGB information on a vertex-by-vertex basis. This can be easily incorporated into the point data format description. However, in future applications of TLS, imagery, and its orientation parameters, is likely to become an additional observation source. To facilitate this it would be useful to retain the information providing the orientation and image itself. However, this is beyond the scope of the data format itself and is an excellent example of the concept of a delivery standard.

4.6.4 Metadata requirements

Although the detailed metadata responsibilities lie with the delivery standard it would be useful for outline information to be provided should the format become detached from the delivery standard. A simple record describing the contained data is sufficient for this purpose.

4.7 Gaining acceptance

Identifying required alterations to the LAS format is relatively easy task. One of the harder, but very necessary tasks will be to persuade developers and software vendors to incorporate the facility for exporting collected datasets in the new format. This will require the cooperation of users, data providers and instrument vendors to fully achieve this aim. One of the initial processes will be to provide working examples of export and import modules for available software. These tools will need to support batch processing of files to make the export of large projects easier. As part of the Heritage3D project, demonstrations, in conjunction with commercial software developers, will be provided within existing software solutions.

The result of this revised data format, if it becomes widely used, will ease the transfer of TLS data between data providers and provide a suitable format for archiving point cloud data.

5. SUMMARY

This paper has discussed why professional guidance in geomatics, and specifically TLS, is important and analysed the ways in which it might be implemented. Illustrated with a case study that is aiming to develop professional guidance for the cultural heritage community, the paper has described specific attempts to define a new standard for the storage and archive of data from terrestrial laser scanning. It is anticipated that the use of such a standard format will encourage the use of laser scanning and allow more comprehensive data management to take place. Coupled with the development of three-dimensional data management systems, such a standard may help encourage the commissioning of on-going survey services to provide and maintain subject records as part of a management process, rather than the supply of one off products.

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7. ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of the English Heritage Archaeology Commission, now known as the Historic Environment Enabling Programme (grant number 3789 MAIN) and the ongoing support of the Heritage3D project associates. For a full list of associates please visit the Heritage3D project web site.