# digital cultural heritage: FUTURE VISIONS

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The symposium Convenors received a total of 33 abstracts. All abstracts underwent a double-blind peer review by two members of the Symposium Organising Committee. Authors of accepted abstracts (24) were invited to submit a full paper following presentation of their draft papers at the symposium. All submitted full papers (8) were again double-blind peer reviewed by two anonymous reviewers and given the opportunity to address reviewer comments. Papers were matched as closely as possible to referees in a related field and with similar interests to the authors. Revised papers underwent a final post-symposium review by the editors before notification of acceptance for publication in the symposium proceedings.

Please note that the paper displayed as an abstract only in the proceedings is currently being developed for an edited book on digital cultural heritage.

Innovative new data collection and digital visualisation techniques can capture and share historic artefacts, places and practices faster, in greater detail and amongst a wider community than ever before. Creative virtual environments that provide interactive interpretations of place, archives enriched with digital film and audio recordings, histories augmented by crowd-sourced data all have the potential to engage new audiences, engender alternative meanings and enhance current management practices. At a less tangible level, new technologies can also contribute to debates about societal relationships with the historical past, contemporary present and possible futures, as well as drive questions about authenticity, integrity, authorship and the democratisation of heritage.

Yet for many, gaps still exist between these evolving technologies and their application in everyday heritage practice. Following the success of a sister conference in Brisbane, Australia in April 2017, this symposium focused on the emerging disciplines of digital cultural heritage and the established practice of heritage management. The symposium aimed to provide a platform for debate between those developing and applying innovative digital technology, and those seeking to integrated best practice into the preservation, presentation and sustainable management of cultural heritage.

The symposium was designed to encourage critical debate across a wide range of heritage-related disciplines. We welcomed papers from practitioners and academics working in cultural heritage and related fields such as architecture, anthropology, archaeology, geography, media studies, museum studies and tourism. We particularly encouraged papers that explored the challenges of digitising tangible and intangible cultural heritage, those that identified issues with digitisation and digital interaction, and those that addressed the theoretical challenges posed by digital cultural heritage.

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EDITORS and SYMPOSIUM CONVENORS

*digital cultural heritage:*
*FUTURE VISIONS*
*London Symposium*

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# 3D Laser Scanning Built Heritage: St Boniface´s Church as a Teaching Eexperience

**Abstract**

*The use of new technologies to record existing architectures is increasing as they become cheaper and more accessible than ever before. Among them, 3D laser scanning (also known as LiDAR) is of particular relevance for surveying built heritage since it can provide full documentation of the reality in the form of a three-dimensional coloured point-cloud, measurable and with a precision of millimetres, in a short period of time. Although its use is not new, especially in the subject of cultural heritage, its inclusion in architectural education is recent. The quality and comprehensiveness of the data, from which architectural drawings are obtainable at any scale, among other products such as images, videos, and 3D printed models, challenges the traditional way of surveying buildings and can have further implications for architectural studies. This paper reflects on the first teaching experience of 3D laser scanning applied to built heritage at The Bartlett School of Architecture, UCL, which challenged previous uses of this method by capturing a complete building and generating architectural products from it in a few classes. Using the case of St Boniface´s Church in London, the objective of this paper is to account for and reflect on the data obtainable in just one day of on-site 3D laser scanning capture. Framing these products within a brief revision of surveying methods of buildings over time, the paper establishes the importance of 3D laser scanning for recording built heritage. The workflow of on-site data collection, processing and model making in only a few sessions is presented as a way to speculate over new architectural possibilities when the reality is available as-built with accuracy. Approaching an era where almost everything can be captured digitally might have implications for the way the physicality of historic buildings is perceived and preserved.*

**Keywords:** 3D laser scanning; St Boniface´s church; Built heritage; Surveying; Teaching

### Surveying heritage buildings

Over time, buildings have been recorded using different techniques, which has had a direct impact on architectural representation. However, it is hard to find evidence of that process before the Renaissance and the architectural treatises of that period.

> We can find the roots of modern architectural representation in a large body of drawings surviving from the sixteenth century onwards. The evidence is more sparse from earlier times. Virtually nothing survives from antiquity and the early Middle Ages — some Egyptian papyruses, the marble plan of Rome, a newly discovered full-scale elevation of the pediment of the Pantheon, and the parchment plan of the abbey of St. Gall being notable exceptions. (Ackerman 1997, 41)

There is no clarity around how these drawings captured the measurements of the buildings they represent, which leads to the question of how accurate they are. There is also no certainty that these drawings had the purpose of representing something already built. Before the concept of scale drawing existed, Ackerman (1997) notes that full-scale drawings of massive constructions were often drawn on the ground. Similarly, engravings of as-built windows and spires have been found in the masonry of buildings, suggesting an embedded process of design based not only on verbal communication, but also on models and templates. This suggests that scaled architectural drawings were not needed for the construction of new buildings.

> Architecture has not always been an art of drawing. For much of history, right up until the Italian Renaissance, architecture was a mechanical craft, and buildings were conceived and made by artisan workers who laboured and toiled on building sites, cutting stones, laying bricks and sawing timber. (Carpo 2013, 128)

Therefore, the construction *as-built* would be the best source of information and how measurements are extracted from it would define the accuracy of that operation. From proportional units and methods to the use of the most advanced technology, surveying heritage buildings is a task that has improved over time mainly regarding the quality of the result in relation to the time invested.

> Primitive practices make use of a familiar 'yardstick' as a unit of measurement. Sources of measuring yardsticks are usually the human body, or the structure itself. The human source provides measuring units as the person's pace, handspan, or height. Such units are obviously handy and convenient. (Elwazani 1989, 84)

However, precision was an issue. Proportional drawings and sketches 'based on counting uniform construction units' (Elwazani 1989, 84), are still used as a way of taking fewer measurements on-site; 'the rest is estimated by proportion' (Elwazani 1989, 85), although not suitable for the documentation of important structures due to its low accuracy.

Hand-measured drawing is probably the most known and used method for surveying existing buildings, with a precision that would depend on the surveyor´s experience and type of structure. Triangle methods,[1] and the use of complementary instruments, such as levels,[2] theodolites,[3] plane tables,[4] and more recently digital laser measurers, would improve the result. Other complementary devices, such as the adjustable combs,[5] were used until the 1980s and were key to obtaining the shapes of intricate details — for example, mouldings — that were then transferred to paper. These methods are still used in architectural education, not because of their accuracy but as a way of observing the reality in a spatial way, and to develop representational tools in which drawing — especially drawing by hand — can remain relevant to the discipline, particularly given the current digital emphasis in education.

Photography is commonly used as a complementary technique for surveying buildings since it is fast and accessible. Although it cannot capture dimensional information directly from the built reality, measurements can be extracted from photographs with the techniques of rectified photography, photogrammetry and stereo-photogrammetry. The latter allows for the creation of three-dimensional digital models using several images of objects and specially created algorithms. However, these are better for documenting objects, murals paintings and details, rather than for surveying architecture. The limitations of photogrammetry include difficulty in applying the technique to large-scale buildings, and how expensive it can become when high accuracy is needed:

> It is almost impracticable to obtain complete photogrammetric archives covering the very minutest detail when the subject is a major building. Defining the specific purpose of a survey is certainly one of the most important tasks over which architects and photogrammetrists must help one another. (ICOMOS 1968, 162)

Despite the advances in photogrammetric techniques nowadays, it is time-consuming to obtain quality data of complete structures using it. This is why it is common to find a combination of these methods to obtain a metric survey of a building, especially if cultural artefacts and works of art are part of it. In the context of technological advances, these methods will become outmoded rapidly, which is why the focus of this paper is not on describing them.

One of the techniques that has had the most impact on the way heritage buildings are currently surveyed is 3D laser scanning. It is an efficient way — in terms of time and resources — of accurately recording historical environments compared to the previously mentioned methods. There is a range of 3D laser scanning techniques described, classified, and exemplified with case studies by current literature. For example, Historic England (2018) provides guidance for the correct selection of methods and

their application to the surveying of built heritage. The most popular ones, which involve capturing the reality by projecting light over a surface to digitally reconstruct its geometry — for example, the Sense 3D Scanner — are limited in range; useful for objects, but not for capturing entire built spaces. Simpler imaging techniques used to generate a three-dimensional model of an object use principles of photogrammetry and stereo-photogrammetry — such as Agisoft. From them, this paper focuses only on 3D laser scanning using a terrestrial Faro Focus x330, mounted on a surveyor tripod.

In this method, the measurements are taken by a rotating 360° laser beam, which captures millions of points of the surfaces it hits. Then, a photo camera, embedded in the scanner, takes photographs to colourise the points, creating a three-dimensional digital model of the reality with a precision of millimetres. It captures everything in sight, even those elements that were not initially intended to be part of the survey. 3D laser scanning is not a new technology,[6] but has developed rapidly. The equipment is still expensive, although half the price it was a couple of years ago, ranging from £40,680 to £50,325 depending on the model.[7]

Currently, surveying heritage buildings will usually consider a mixture of methods, defined according to the importance of the structure and the time and funding available for that task. 'Few buildings are surveyed using a single technique. A number of techniques, both direct and indirect, are commonly deployed and the data integrated to obtain a finished survey' (Bedford and Papworth 2009, 4).

However, since 3D laser scanning could be seen as the most comprehensive of those methods in terms of obtaining measurable data of buildings in a short period, it can — even if used alone — provide the information necessary for an almost complete architectural survey of a building. Thus, this paper focuses on testing that principle in an educational context, by applying and understanding the 3D laser scanning process as a practical teaching experience.

3D laser scanning is being taught in a series of elective classes open to students and staff at The Bartlett School of Architecture, University College London (UCL), covering the general aspects of the method through to its specific applications for built heritage[8] and virtual reality.[9] The aim of these classes is to provide a practical set of tools for operating and post-processing 3D laser scan data in order for participants to use and apply this knowledge in their research and designs. Critical thinking is encouraged at the beginning of the course by showing a series of examples of the scanner's use in innovative ways that can inform architectural approaches, yet not limited only to the discipline. By enabling the participants to interact with the 3D laser scans directly, they can discover their own ways of applying and thinking about the threshold between digital and real.

In the two sessions of classes focused on the general method, part of the school's building is scanned with the students who first learn how to operate the equipment, and then how to post-process the data and create images and videos. Figures 1 to 4 are some images obtained using two scans done during classes, which took less than seven minutes each.

The built heritage classes of 2016-2017 academic year considered the 3D laser scanning of St Boniface's church in London, a case defined by the Survey of London, based also at The Bartlett School of Architecture. Focusing only on that building, the objective was to generate a complete survey, testing if it can provide all the measurements required to create detailed technical drawings for architectural purposes, considering a limited scanning time of one day on-site. This was a constraint to test how much could be done in a short period, in order to make easier comparisons with other surveying techniques, but also to create a scenario that would have reduced costs, since one of the expensive parts of a 3D laser scanning survey is accessing the equipment. As a complementary objective, the idea was to share the products created from this survey with the community involved in the building selected, with the potential of being used for



Figure 1. Aerial view of 22 Gordon Street, London, where The Bartlett School of Architecture is located. It was rendered using only one scan done outside the building during the first general class in 2017. (Source: author).
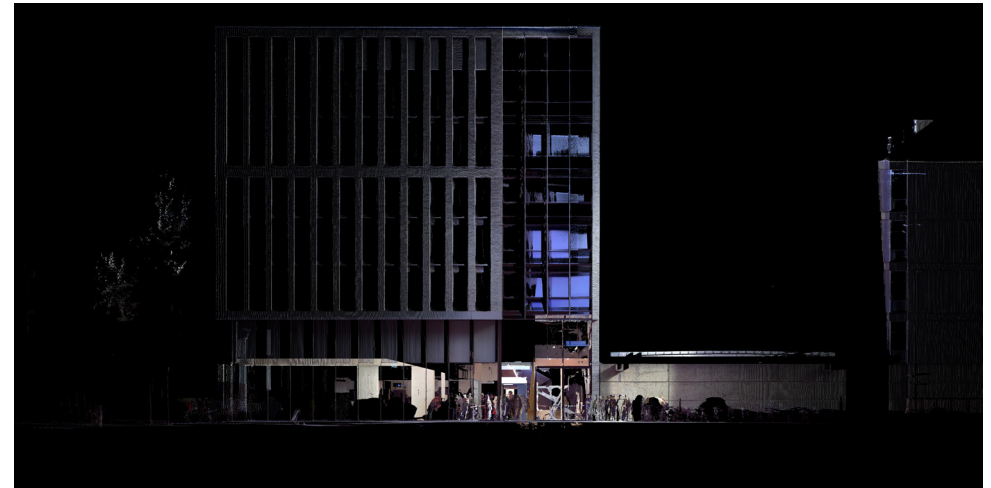


Figure 2. Elevation of the main façade of 22 Gordon Street. (Source: author).

future repairs or retrofitting projects or just as new forms of representation.

These built heritage classes consisted of five sessions that covered the whole workflow of scanning: introduction and planning of a 3D laser scanning survey (half a day); on-site 3D laser scanning of St Boniface's church (one day); alignment of the three-dimensional data (half a day); digital drawing (half a day); meshing and modelling (half a day); and 3D printing (two day workshop). These sessions built upon the contents of the general method classes, allowing a more specific focus on architectural applications and the discussion of 3D laser scanning implications for the preservation of historical environments.[10] The classes are practical and technical based on the assumption that covering the whole process of 3D laser scanning on-site to post-processing would enable students to understand the logic behind this method. Since the principles are common to similar scanning techniques, this approach would allow participants to adapt to new technologies in the future.

### St Boniface's church

The current Roman Catholic Church of St Boniface is a post-war building located in Adler Street in London, built in 1960. It is a distinctive example of modern architectural design. The current building replaced the previous church, which was 'entirely destroyed in September 1940 by a high-explosive bomb' (Survey of London 2016). The initial design was done by the German Architect Toni Hermanns in 1954, which was rejected by The Archdiocese. The design was then revised by Plaskett Marshall & Partners, obtaining approval 'in 1957 after debate over the cubic or auditory nature of the main space, progressively non-processional for a Catholic congregation at this date' (Survey of London 2016).

This church was selected as a case study for several reasons. First, the nonexistence of architectural drawings of the building, so the surveying of it *as-built* was relevant for the work of the Survey of London. Second, its size and simple spaces helped the task of completing the 3D laser scanning in only one day.
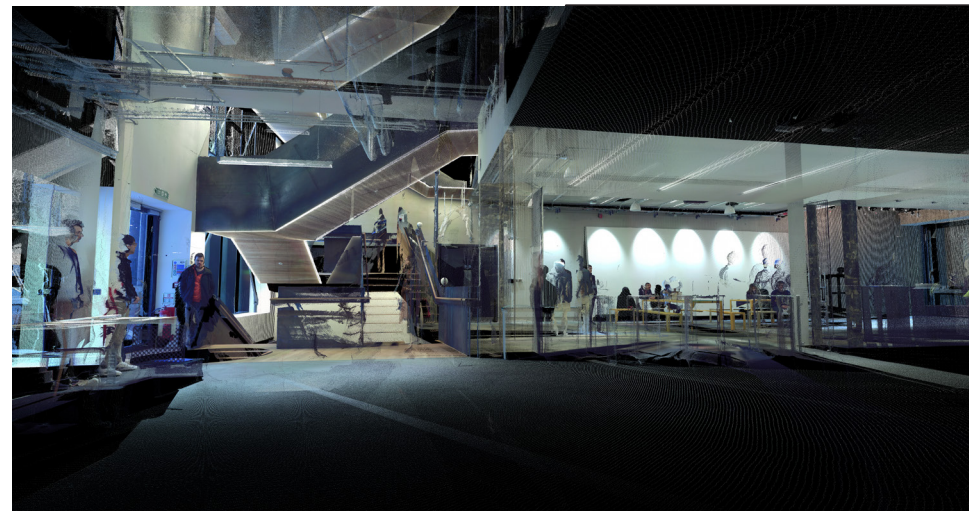


Figure 3. Interior view of 22 Gordon Street. (Source: author).



Figure 4. Interior section of 22 Gordon Street using only two scans. (Source: author).

Third, the church has embedded artworks within its structure that could be documented along with the rest of the building, such as a mural on the altar wall, decorated railings and carved wood details.

### 3D laser scanning on-site survey

As the main area of the church is one only large space, not interrupted by columns or other elements, it was captured by only a few scans, giving extra time to capture the exterior, access space, narthex and presbytery. During the survey, spherical and paper references were used, and the scanner was moved into different locations in order to capture the whole building.[11] As the 3D laser scanner only captures surfaces, to get the exterior façades of the building, it was required to scan from the streets. One of the challenges of doing this was the weather since the model of 3D scanner used cannot operate when raining. The survey was adjusted accordingly to scan exterior spaces when the rain stopped temporarily, obtaining 28 scans in total that captured millions of points.[12]

Since the 3D scanner model used is terrestrial, aerial information cannot be captured from the street level, unless the scanner is placed in a higher position. In this case, it was possible to capture aerial data of the church's roof and its surroundings from the roof terrace of an opposite building (Figures 5 and 6).[13] Another limitation of 3D-laser-scanners is that they capture everything in sight, which means that unwanted elements can interfere in the target — such as trees and people. Automatic filters are embedded in the post-processing software[14] to discard irrelevant information and noise from the scene, improving the desired visual product. Manual editing can also help to eliminate unwanted information, which increases post-processing times.[15] Considering the comprehensive outcome, these limitations are minor, and most of them are currently overcome by the latest developments in hardware and software, as the technology is advancing fast and complementary equipment is currently on the market to help fill possible voids during the scanning process.

### Post-processing and creation of products

The post-processing of the data captured on-site was done during the following three sessions of the course. Besides digital navigation, the resultant 3D point-cloud was used to generate a series of sub-products, such as images (Figures 7 to 9). The information was also used in black and white despite being captured in full colour (Figure 10). Sectioning the point-cloud allowed technical views to be generated — plans, sections and elevations — that can be rendered and printed later at any architectural scale (Figures 11 to 17). However, technical vector drawings are most common to use as a survey product for heritage buildings, for which the technical views served as a measurable reference upon which to draw (Figure 18).

As with any other representation method, 3D laser scanning offers its own particular aesthetic quality. However, the transparency and immateriality of the rendered images contrasting with the physical building they depict are a subject left for further studies. The relevant aspect to mention here — in terms of



Figure 5. 3D laser scanning from the roof terrace of a hotel opposite to St. Boniface's church in London. (Source: author).
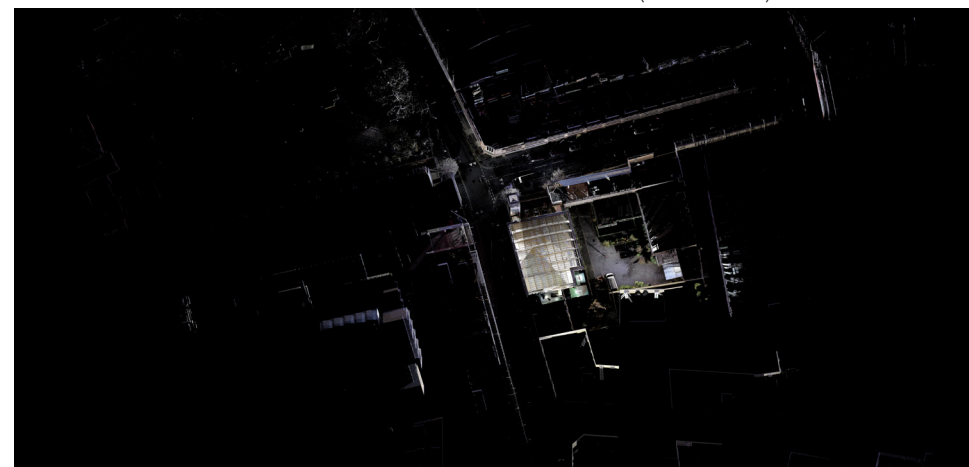


Figure 6. Top view of St Boniface´s church and its surroundings, rendered from the 3D laser scanning survey done in December 2016. (Source: author).

representation — is the fact that as the images from 3D laser point-clouds are computer generated, they might mislead the viewer as portraying something that is not real, despite representing probably the most precise record of St Boniface's church done so far. To avoid that, the black background has been chosen by the author as a way to distinguish and avoid confusion with digitally created models or other forms of documenting, such as photographs. This is relevant to mention in the context of the widespread use of digital modelling to recreate the previous status of constructions and augmented reality mainly for touristic purposes in the cultural heritage domain.

In the last session, the three-dimensional aspect of this 3D laser scanning survey was better conveyed via the creation of models. While in architecture, models are usually created as a medium for designing buildings, in this case, the models were created from an *as-built* condition, as a way to represent reality. This reverse operation potentially allows us to capture and transform any existing architecture into a miniature scale, and to replicate it as much as required, with implications for the originality and authenticity of the heritage building. In order to do this, the 3D laser point-cloud was converted into a mesh, and then into a 3D printable format (Figure 19). Due to the high-resolution of the 3D laser scanning, the data was subsampled, which means using only a small proportion of the points measured to facilitate the conversion process.

The technical views and models (Figures 20 to 22) were created during the final part of the course, a two-day workshop, which included a final open presentation also attended by members of St Boniface's church community. These products were generated by the four participating students and given to the priest of the church, as a way to make the 3D laser scanning survey accessible and potentially useful in the future, especially relevant since there were no updated planimetrical drawings of the church.

In only five sessions and a workshop, corresponding to a total of five days of teaching and practice, the students learned how to use 3D laser scanning in their



Figure 7. Aerial view of the church and its surroundings. (Source: author).



Figure 8. Interior view of the church. (Source: author).

Figure 9. Interior view from over the altar of the church. (Source: author).



Figure 10. Black and white exterior view of the church. (Source: author).

own projects — from capture to post-processing. This experience has a direct implication for surveying built heritage in comparison to a hand-measured method, which, even when complemented with other techniques such as photogrammetry, would have taken more time on-site and to post-process in order to generate similar products, as demonstrated in previous studies (Devilat 2014, 2016).

The complete 3D laser scanning survey of St Boniface's church needed on average six persons and one day of on-site data capture (six person-days). Alignment of the 3D data was done by one person in two days (two person-days). The creation of images and technical views was done by three persons in two and a half days (seven and a half person-days). The creation of a linear plan drawing from 3D data was done by one person in four and a half days. Finally, the creation of digital models and 3D prints was done by two persons in two and a half days (five person-days). This would be a total of 32 person-days.

Even if a similar survey could be done in the same period, 3D laser scanning offers more possibilities and stands as a more comprehensive record due to its three-dimensional quality, leading to further uses (Figure 23).[16] This potentially eliminates the need to define its purpose *a priori* and generates a digital record that can serve for other uses in the future. In this regard, documenting the reality using 3D laser scanning is being used internationally for built heritage at risk, creating digital models that can persist over time beyond their physical version, for example, Cyark.[17] Archiving the surveying material generated then becomes key. This is why the data created in the teaching context of the classes is uploaded to The Bartlett 3D Scan Library, an online archive of 3D laser scanned buildings,[18] which might have an essential role in the future.

As the first teaching experience of this kind at The Bartlett School of Architecture, UCL, measuring its impact can be difficult since its implications and applications are embedded at many levels in students' designs and research. However, the main objective

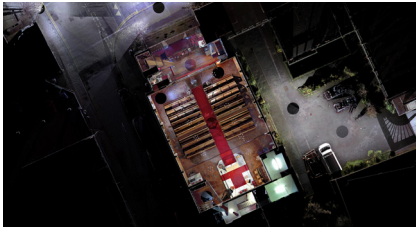Figure 11. Isometric view of the church. (Source: author).



Figure 13. First-floor plan of the church. (Source: courtesy of E. Savvidis and M. Daouti).



Figure 15. West façade elevation of the church. (Source: author).



Figure 17. Transversal section of the church. (Source: courtesy of E. Savvidis and M. Daouti).



Figure 12. Ground floor plan of the church. (Source: courtesy of E. Savvidis and M. Daouti).



Figure 14. North façade elevation of the church. (Source: courtesy of E. Savvidis and M. Daouti).



Figure 16. Longitudinal section of the church. (Source: author).

of the course, to enable students to use this method in their own projects, is exemplified by the work of Anastasios Theodorakakis for St Dunstan in the East, London, which stands out as a form of enquiry regarding that space as a real/digital palimpsest (Figure 24).[19]

## Conclusion

With the availability of a measurable 3D model of the reality provided by the laser scan data, the way of surveying buildings is adapting and updating. Its convenience has the potential to change how we intervene and preserve historic buildings. Such an accurate and fast recording method has not been widely available before, which has direct consequences for their replication and digital presence beyond the physical building. This is also relevant since it leads us closer to the idea that more heritage buildings can be documented in a more comprehensive way, where the method applied has proven to be useful to obtain a large amount of information in short period of time, even in a teaching context.

Providing access to the 3D laser scanning equipment, it has been shown how this method can be taught and practised while carrying out a metric survey, with challenges the way architectural surveying is usually done. Additionally, the 3D laser scanning can serve as a basis to inform and speed up the production of traditional representation methods, such as the linear drawings of plans, sections and elevations. This has the potential of breaching the gap between traditional and current surveying technologies.

The experience shown challenges the notion of 3D laser scanning as an expensive method, since the compression of the on-site scanning and teaching in only five sessions and a workshop, was a way to render the method as affordable by comparison with the amount of workforce and time that would be necessary to obtain and process the same amount of data with traditional methods. In this regard, the unavoidable and still high cost of possessing a 3D
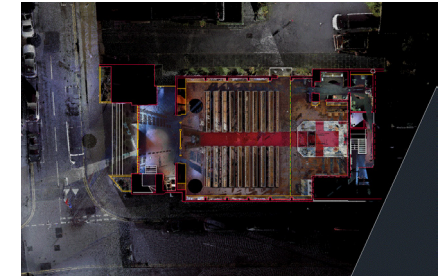


Figure 18. Linear digital drawing of the plan over the 3D laser scanning of St Boniface's church. (Source: courtesy of H. Jones).
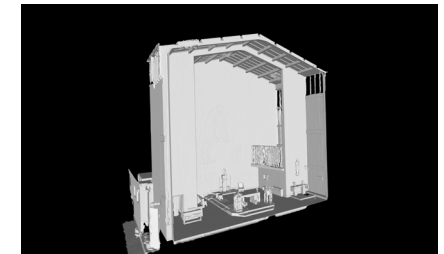


Figure 19. Model of the altar of the church after converted into a mesh using MeshLab software. (Source: author).
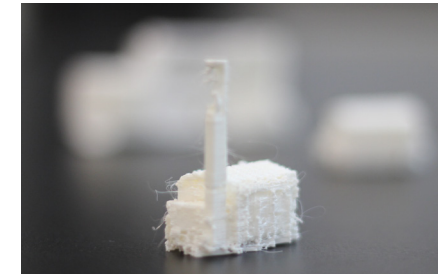


Figure 20. 3D printed models of the church based on the 3D laser scanning data of 2016. (Source: author).
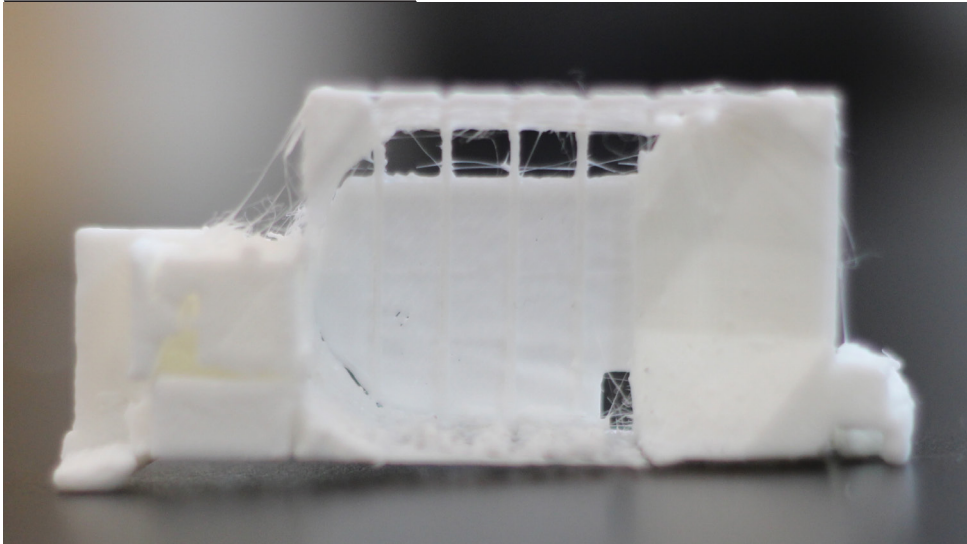
Figure 21. 3D printed models of the church based on the 3D laser scanning data of 2016. (Source: Author).



Figures 22. 3D printed models of the church based on the 3D laser scanning data of 2016. (Source: Author).

Finally, the possibility of capturing almost all spaces of a case study also changes the mindset from an architect's point of view, by providing the media over which detailed and precise interventions can be designed to fit perfectly in the reality. Thus, a longer course could have the potential to extend the study of digital recording technologies in architecture — especially as a method of analysis and research when applied to historical environments — and its further implications.

**Supplementary material**

A video exploring the 3D-laser-scan model of St Boniface's church in London is available from https://vimeo.com/251035025.

laser scanner can potentially be lowered with the alternative of hiring the equipment for just one day.

The three-dimensional quality of the 3D laser scanning record establishes a new standard of documentation where there is no fixed point of view — as with photography — or where the record is limited to what was carried out at a particular moment for a determined purpose. In this case, all the products were rendered after the data collection on-site, with a digital model that is archived for future purposes, potentially going beyond the teaching experience presented here.



Figure 23. QR code to a video showing the 3D-laser-scan model of St Boniface's church in London. Also available from https://vimeo.com/251035025. (Source: author).
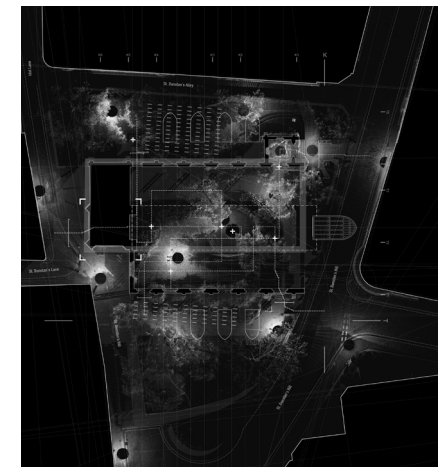


Figure 24. Superimposition of technical drawings on top of the plan obtained from the 3D laser scanning of St Dunstan in the East, London. (Source: courtesy of Anastasios Theodorakakis).

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**Endnotes**

1    Triangle methods 'are based on constructing one or more triangles from identified dimensions on site or on the structure. Not all dimensions are measurable or known, of course. The unknown dimensions are calculated by using the concept of similar triangles or trigonometric equations. Either approach, similar triangles or trigonometry, requires only a few hand measurements; both are suitable for documenting the heights of tall buildings.' (Elwazani 1989, 88-89).

2    'The level is an instrument for determining heights of points on the surface of the earth.' (Elwazani 1989: 103).

3    Theodolites are used to measure angles and dimensions in a vertical or horizontal plane (Elwazani 1989).

4    Plane tables must be 'appropriately located, oriented, and levelled, sight is taken to a target by the alidade. A line is, then, drawn along the alidade rule. This line represents the direction tying between the station point of table and the target.' (Elwazani 1989, 114).

5    'It consists of a row of parallel metal plates that can slide in a metal carriage. When measuring, the plates are pressed against the molding; the shape thus formed is then transcribed to a drawing.' (Elwazani, 1989, 76).

6    The National Research Council of Canada was among the first institutes to develop the triangulation-based laser-scanning technology in 1978. The specific 3D-laser-scanning type used in this exercise — which is based on portable features and light detection — was invented and patented by Ben Kacyra and Jerry Dimsdale in 1998. Source: Wikipedia: https://en.wikipedia.org/wiki/CyArk [Accessed 16th May 2018].

7    Excluding VAT (20%). Source: Faro Europe quotation for new and latest models. Older models are discontinued but would be cheaper if bought second-hand. Maintenance would add a cost of approximately £2,500 per year, depending on the model.

8    3D laser scanning general and built heritage classes are taught by the author.

9    Taught by Fiona Zisch. During the first year of implementation (2016-2017), there was an additional subject on fabrication and robotics where, for example, the 3D laser data was used as environmental data to calibrate robotic arms.

10   The role and impact of 3D laser scanning for heritage contexts at risk of disappearance is further studied in the author's PhD thesis: 'Re-construction and record: exploring alternatives for heritage areas after earthquakes in Chile' supervised by Professors Stephen Gage and Camillo Boano.

11   The on-site 3D laser scanning was done by the author with the help of 12 students during one day in December 2016.

12   890,064,288 points exactly.

13   Aerial drones are commonly used for capturing data from above to complement terrestrial scanning.

14   Scene 5.5 was used.

15   Pointools Edit Pro 1.5 was used.

16   Additionally, the author has created a video from the 3D laser scanning point-cloud, since its three-dimensional quality is better disseminated as a video that can be seen on any device, considering that the high resolution of the points captured require powerful hardware to be visualised otherwise. Available from: https://vimeo.com/251035025

17   http://www.cyark.org/ [Accessed 16th May 2018].

18   https://bartlett3dscanlibrary.com/ [Accessed 16th May 2018].

19   Available from: https://bartlett3dscanlibrary.com/2017/10/01/st-dunstan-in-the-east-city-of-london/ [Accessed 16th May 2018].