SUSTAINABLE ARCHITECTURE: RESTORATION OF THE FACADES OF HISTORIC BUILDINGS USING MODERN METHODS

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Abstract

This paper presents a comparative study of different methods used in building front reconstruction. It compares modern methods of automatic image acquisition and processing of building fronts which have been subject to degradation. The first method presented involves using data captured with a drone. The drone captured multiple photos which have been stitched together using software to create an orthophoto map. This map was then used to vectorize the image, by using the Vector Magic software which automatically transforms a raster intro a vector network. The second method presented takes a different approach by creating a point cloud of the building directly with the help of the Leica Scan Station 2. A comparative study is presented, by showing the advantages and disadvantages of both methods, as well as their similarities and differences.
We can note from this study that a reliable solution for conservation and restoration of historical buildings is available by combining modern technology and known software solutions.

Key words: facade, restoration, Point Cloud, Vector Magic.

INTRODUCTION

Buildings' façade mapping is one of the most important procedures in urban design as provides the basis for the urban scene analysis and the evaluation of the quality of the built environment. The current most used procedure for mapping a buildings' facade capturing photographs, scaling them with measured distances and then manually tracing the façade edges using CAD software (Attya & Habib, 2013).

This method is limited by the omission of the geo-referencing process which makes it possible to add the façade maps as details to mass-block 3D city models.

Enriching 3D city models with building's façade details is crucial for many applications such as urban scene analysis, heritage conservation, urban recognition and visual navigation among many others (Attya & Habib, 2013).

The digital 3D survey of building façades represents a well-established issue, which has been improved in the last 15 years thanks to the introduction of several active and passive digital systems (Carnevali et al., 2018).

The introduction of light UAVs (Unmanned Aircraft Vehicle) or RPAS (Remotely Piloted Aircraft Systems) equipped with digital camera seems to be in such sense the best solution to acquire hidden or unreachable building areas, overcoming terrain limitations (Carnevali et al., 2018).

Compared with aerial photogrammetry, close range photogrammetry and particularly architectural photogrammetry isn't limited to vertical photographs with special cameras.

The methodology of terrestrial photogrammetry has changed significantly, and various photographic acquisitions are widely in use (Grussenmeyer et al., 2002).

Close range photogrammetry is a technique for obtaining geometric information, e.g. position, size and shape of any object that was imaged on photos before (Grussenmeyer et al., 2002).

3D surface information can be obtained efficiently via remote sensing technologies applied to UAVs at close range domain. Spectral images provide spectral features whereas LiDAR point clouds contain 3D spatial features (Popescu et al., 2017).

The building that is the subject of the study is one of the oldest buildings belonging to the university, where chemistry classes are held.

MATERIALS AND METHODS

Standard Method
The measurements were taken with a Leica Scan Station 2 (Figure 1). 3D Laser Scanning, also known as terrestrial LIDAR, has been commercially available for several years, providing a detailed, reliable, and accurate solution to many surveying and measurement problems (Marinescu et al., 2013; Popescu et al., 2015).

Figure 1. Leica Scan Station 2

Terrestrial laser scanners produce a dense point cloud of an object's surface.
For many applications a reconstruction which is as close to the original as possible is required. The most typical example is the visualization of the scanned data. In many respects, laser scanning follows the same general surveying process as other instruments: data is collected in the field, adjusted to the appropriate coordinate system, and relevant features can be extracted to produce deliverables ranging from topographic maps, coordinate values, 2D or 3D CAD drawings (Marinescu et al., 2013).

Image acquisition
DJI Phantom 3 Professional drone was used. The drone flew on a single altitude band with the camera pointing perpendicularly to the facade of the building. It took off from the ground and flew in parallel with the building until it reached the roof (Figure 2) (Erghelegiu et al., 2018).

Figure 2. DJI Phantom 3 Professional

The building that is the subject of the study is one of the oldest buildings belonging to the university (Erghelegiu et al., 2018).

Data process
The photogrammetric data were processed in Vector Magic and AutoCAD software.
Vector Magic analyses the image and automatically detects appropriate settings to vectorize it with, and then goes ahead and traces out the underlying shapes in full colour.
Vector Magic uses the blending to make the vector result resemble the input image as closely as possible (Figure 3) (https://vectormagic.com/)
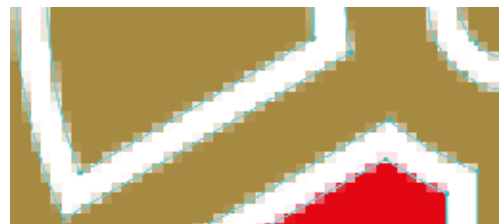

Figure 3. Automatic vectorization

Vector Magic carefully traces out every pixel in image, slicing each edge pixel at precisely the right spot to re-create the intention of the original.
Graphics recognition is conceded with the analysis of graphics-intensive documents, such as technical drawings, maps or schemas. Vectorization, i.e. raster-to-vector conversion, is of course a central part of graphics recognition problems, as it deals with converting the scanned image to a vector form suitable for further analysis. Many

vectorization methods have been designed throughout the years, and several software packages are available. Thus, in one sense, the basic raster-to-vector conversion problem might be solved. However, there is still a major problem of precision, robustness and stability of the vectorization processes (Tombre et al., 1998; 1999; 2000).

RESULTS AND DISCUSSIONS

As a result of taking pictures with the help of the drone, we obtained the orthophoto map which includes the facade of the building following the steps in the scientific article published last year by Erghelegiu et al., 2018.
Thus, continuing the research, we digitized the obtained image automatically through the Vector Magic processing software.
The vectorization process takes a minute or two, depending on how fast processor is. Once it is done, we will find the result on the "Review result" page. On this page, we can quickly reprocess the image with slightly changed settings, or we can edit it manually.

Figure 4. Computing the vector map.

The first step involved the insertion of the desired image and the selection of the accuracy parameters that are desired for a fairer vectorization of the façade (Figure 4).

Figure 5. Removing background vectors

After obtaining the automatic result, we proceed to the next step, namely the one in which the vectors that are not part of the studied object will be removed, vectors such as those representing the background of the image (Figure 5).
The segmentation editor works is a similar manner to Microsoft paint, or any other simple bitmap editor. It allows the user to make manual edits to a course, pixel-aligned version of the vector image. This is particularly useful for correcting mistakes like this one, where the wrong shapes are connected.

Figure 6. Exporting vectors in dxf format

The result obtained can be exported in several formats, as well as the one in "*.dxf" compatible with CAD software. This step is exemplified in Figure 6.

Figure 7. Preview of vectors-network

Here is another view that shows the outlines from the vector image superimposed over the original bitmap image. As we can see, nodes are generally placed in very sensible locations, and the vector image very closely follows the actual shape boundaries in the original bitmap. That the edges in the vector image slice right through the anti-aliasing in the original bitmap is one of the best features of Vector Magic in comparison to other auto-tracing tools. Figure 7

shows the vector network superimposed over the image layer for a more objective analysis.

That takes us to the page for saving our vectorized result to the hard disk or dragging and dropping it on another program. In this case, we've elected to use the "Quick Save" feature. Quick save allows us to save the vectorized result to the specified directory and using the specified file format with a single click.

The next step is the standard method of determining point cloud on the building façade as a comparison with the previous method.

Terrestrial laser scanning technology allows measurement of a larg number of points placed on the object monitored without the need for them to be accessible but only visible. The principle of laser scanning system is very simple; the scanner emits a laser beam that is reflected from the object. When measuring a characteristic point on the surface of the object, three observations are made: slope distance and two angles - horizontal angle and vertical angle (Calin et al., 2015).

In AutoCAD, we can create models in a conventional way. AutoCAD, however, comes with a programming environment (more than one), with which we can create a set of instructions, including the rules and constraints of the design (as well as parameters defining certain aspects of the design), which can be used to build the model. We can use these instructions to always build a model from scratch, each time using the same parameters, or experimenting with different ones.

We can create a TIN surface from points within RCS format point cloud scan files and RCP format point cloud project files created with Autodesk® ReCap™.

We can use the Create Surface from Point Cloud command to create a surface from several point clouds, selecting only the areas that we want to include and filtering out non-ground points, so they are not included in the resulting surface. When using this command, we can select entire point clouds or areas of point clouds to include in the surface. We can select areas of point clouds by using window selections, by defining polygon areas, or by selecting existing closed polylines in the drawing.

In the following figure we can analyse the result obtained by scanning the facade and obtaining the cloud of points (Figure 8).

Figure 8. Point cloud of the facade

The point cloud renders every detail of the facade very precisely with a modelled surface precision (noise) of 2 mm, an scan resolution of 6 mm (Gaussian - based) for position and 4 mm (FWHH - based) for distance at a range of 0 m-50 m, the maximum range being 300 m at 90% (134 m at 18%) and a maximum instantaneous scan rate up to 50.000 points/sec.

A point cloud is a large collection of points acquired by 3D laser scanners or other technologies to create 3D representations of existing structures.

Point cloud files support the design process by providing real-world context where we can recreate the referenced objects or insert additional models. Once a point cloud is attached to a drawing, we can use it as a guideline for drawing, change its display, or apply a colour stylization to distinguish different features.

Sectioning a point cloud provides another way for us to extract the geometry from it. The PCEXTRACTSECTION command identifies the underlying 2D geometry in the point cloud and creates a 2D line drawing. By default, the geometry is created on a plane coincident with the section plane (Fei Dai & Ming Lu, 2008). We can define the geometry that we want to extract, the layer on which it is created on, the colour of the resulting 2D lines or polylines, the width of the polylines, and the tolerance settings.
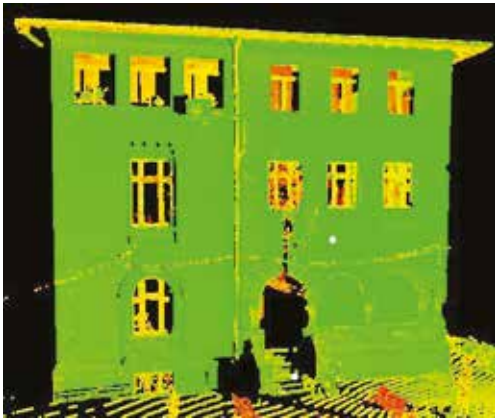
Figure 9. Facade Model from Point Cloud

Deliverables can be extracted straight from the point cloud without further processing, or by first creating a 3D surface model from the point cloud and extracting the deliverables from this surface model (Figure 9).

Building models can be explicit. Every aspect of the model is well-defined and can be described, typically independently without referring to other parts of the model. In a computer model in which a building is represented explicitly, we can, for example, get the coordinates of any point in the building, and from this information, even create various representations (such as plans and sections, renderings, physical models), and even create the real building. During the design process, where decisions about the building are being made as the model is being built, aspects of the model are built, tested (by various methods), and continually modified (Neil et al., 2008).

CONCLUSIONS

Both methods are usable in the reconstruction of building fronts. The method presented in this study which uses a laser scanner to create a point cloud of the building front is more accurate and precise, when compared to the method which involves using images captured by drone.

It is recommended to use the drones to acquire images of a building with complex details and 3D laser scanning of those elements. The two methods are complementary.

The 3D scanning method is a precise method that can recreate the facade of the building with superior accuracy using the cloud points taken, but at the same time it also presents disadvantages through the high price of the instrument and related software, as well as a thorough knowledge of the data processing.

The greatest advantage is the using a point cloud we have the possibility to extract any information we need to determine surfaces or other details.

3D models of building components or construction resources have been largely created by computer-aided-design (CAD) or by proprietary code for virtual reality development. Such 3D modelling methods entail accurate definition of points, lines and their relationships in the spatial coordinate system. Unlike CAD modelling, the surveying technique of photogrammetry takes a completely different approach by deriving metric information about an object through measurements conducted on photographs of the object. The very basic technique of photogrammetry is effective and computationally simple. With much less efforts, digital cameras and photogrammetry software have made possible 3D reconstruction of an object in digital form (coordinates and derived geometric elements). The resultant 3D models may well satisfy application needs in construction simulation visualization.

The method in which the drone was used to acquire images is less precise but faster, and the software used is cost-effective and easy to use.

Thus, depending on the desired accuracy, one of the two methods can be used.

It is recommended to study the facade of the building before acquiring the data and to determine the best method according to the complexity of the details to be recreated. In some cases, both methods can be used to increase the quality of the final product.

Architectural façade mapping is one of the important tasks in wide range of geospatial applications. Existing 3D mass-block city model was used in this research to obtain control points for façade mapping. In order to reconstruct the facades of buildings, both 3D scanning and photogrammetric methods using drones can be used, and the images are further processed with software such as those presented.

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