CLOSE-RANGE PHOTOGRAMMETRY AND LASER SCANNING – DATA FUSION AND COMPLEMENTARY APPROACH FOR THE DOCUMENTAION OF COMPLEX OBJECTS

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Abstract:

For the documentation of complex objects different surveying techniques are available. Sometimes a single method is insufficient to capture the entire object. In most cases only one acceptable measurement method is a priori selected and defines the kind and resolution of the collected data. For an enhanced 3D documentation of complex objects the acquisition of single points for linear structures can be combined with point clouds using an optimized combination of close-range photogrammetry and laser scanning. In the project shown not only a combination of methods for a complete data collection was planned but also a complementary evaluation strategy of the archived measurements.

The test object is a guided lime tree, a so-called "Tanzlinde", in Limmersdorf, near Bayreuth, Germany (Figure 1). In former times these "buildings" were used for tribunals and folk festivals. Trough the mixture of a man-made structure and guided lime tree the result is an irregular netting of various geometrical shapes. This very complex object is well suited to test the idea of a combination and complementary use of different surveying methods.

1. Introduction

At guided lime trees the branches are formed building horizontal roofs and ceilings consisting of twigs and leaves, which are supported by rafters and columns. This ring of branches often is followed above by several are formed rings. This way bowers and halls are built with walls made out of leaves even containing windows. In former times on the treetop people were dancing and underneath sometimes even court hearings were held. The forming of the lime trees requires both considerable artistic as well as technical skills and needs the care throughout many generations. Their origins can be dated back to the pre-Christian times [1].

The monument conservators are not only interested in a survey of the dance floor and the geometry of the tree. For the architectural analyses and museum applications also animations, water tide 3D model with sharp edges and clear segmentations between man-made and natural parts of the guided lime trees are requested.

Figure 1: Example of a guided lime tree (“Tanzlinde”) in Limmersdorf, Germany

2. Problem

Many cultural heritage objects consist of a mixture of regularly shapes and irregular surfaces [2]. The constructions can therefore be very complex and usually contain a lot of details. Capturing the whole complexity of the shape gets even more difficult when you have also to consider the offset in depth and occlusion effects for masked surfaces. As an example to demonstrate that problem the “Tanzlinde” at Limmersdorf close to Bayreuth, Germany was chosen. The combination of man-made construction and guided branches of the lime (linden) tree results in a very irregular network of different parts and shapes. Different practical concepts exist for documentation of such structures.

2.1. Point cloud acquisition

Recording an object as a point cloud is a quick method to cover all visible surfaces. Although the point density of recent measurement instruments is very high, this method has its significant weakness in not-capturing the main geometrical characteristics of an object like edges and corners. Another drawback is, that the mutual occlusion and the offset in depth, prevents objects and features from being scanned completely. Sometimes even increasing the number of standpoints does not lead to an improvement of the point cloud when the object parts to be scanned are too close or even touching each other. The reconstruction, based on an incomplete polygon is very time and labour intensive and often anyway does not lead to the desired result (figure 2).

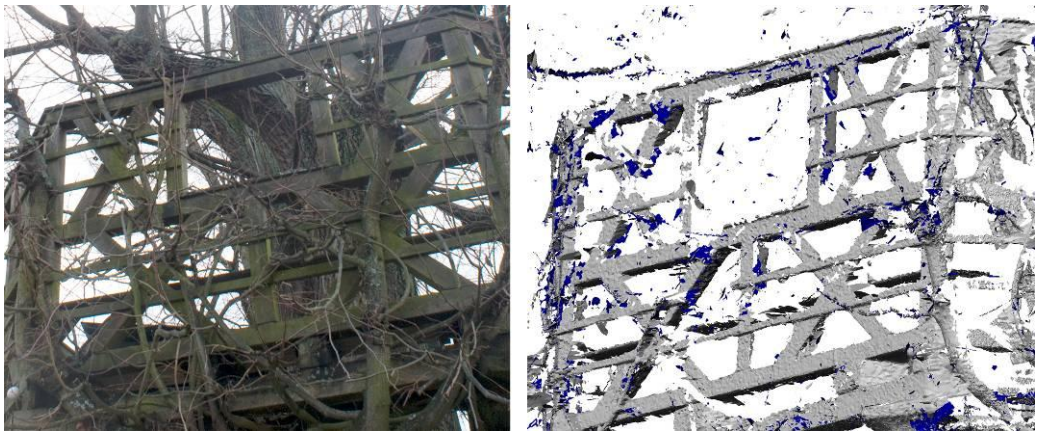

Figure 2: mixture of branches and wooden bars (left) and its draft calculated polygon mesh (right)

Another drawback of point clouds is the unstructured scan and data management of particular parts of the scanned surface. Because of the previously mentioned high complexity of cultural heritage objects an automatic segmentation of the point cloud or the calculated polygon mesh is nearly impossible.

2.2. Single point acquisition

Methods of single point measurement are especially appropriate for objects with a limited number of clearly defined corners and edges. The advantage is based on the explicit survey of basic geometrical shapes. Occlusions from other objects have no effect on the measurement, as long as the corners of structure lines are visible. Using these points the documented shape can often be defined by straight lines and planar surfaces. If the object is very detailed structured or the number of points to be measured is very high, the single point surveying will quickly reach its economical limits. This high effort per point may also negatively affect the objectivity of the documentation.

Anyway the chosen surveying method will have a large impact on the quality and kind of the acquired data. In extreme cases the resulting 3D model does not cover the requirements of the clients and might be useless for further usage.

3. A complementary approach for the guided lime tree

To meet the requirements of the monument conservators for a complete and economic documentation the above postulated method as combination of a single point and a point cloud acquisition was tested. An additional condition was the short period available for the documentation as to guarantee that no leaves of the tree are hiding the required geometry. The only feasible seasons are early spring and late autumn. But, just in this time period the weather conditions in this area are changing quickly. Therefore primarily photogrammetry was used for a fast acquisition of data. Using this method both a processing of single points and a point cloud is possible. Additionally the lime tree itself was documented with a terrestrial laser scanner As the entire object is too huge to be only accomplished with stereo photogrammetry. In this project not only a mixture concerning the collection of data is tested but also different combinations for data evaluation.

3.1. Collection of data

The tight network of branches caused a lot of occlusion in the point cloud of the object. The effort to (mostly manually) fill these holes is immense. A single point acquisition is very useful for the documentation of linear or planar objects like the beams of the dance floor. Eight vertices are sufficient to define a wooden bar as a sharp-edged cuboid. Based on the quick and flexible photogrammetric data collection we got enough imagery from different angles to acquire all needed vertices. An additional benefit is the structuring of data from the beginning for the intended analysis and applications of the monument conservators.

The complex branches of the guided lime tree were documented as a point cloud by a terrestrial laser scanner at a resolution of ca. 10 mm. To define a joint coordinate frame all measurement methods a system of well distributed spherical control points was established around the object.

3.2. Segmentation of the point cloud

A disadvantage of point clouds is the unstructured data. To reduce the amount of work the photogrammetric evaluated surface model was used for a segmentation of the raw laser data (figure 3). The convenience is not only a subdivision of the documented geometry for the following workflow. Such computed polygon meshes of the lime tree are more accurate after the isolation of points of the wooden structure. Poor meshed areas e.g. at the contact points between the branches and bars are reduced this way.

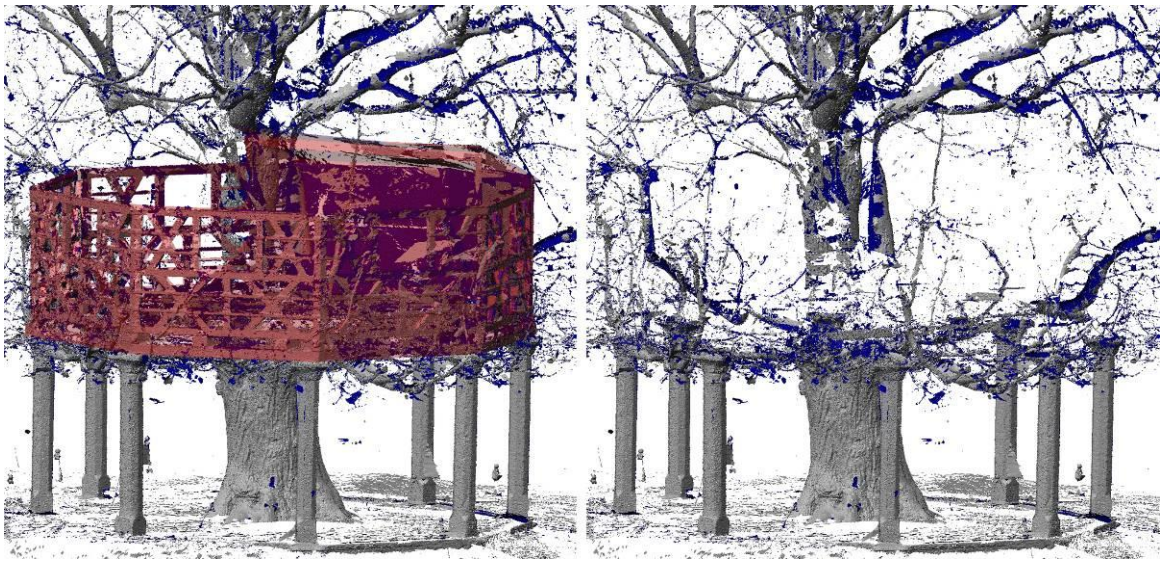

Figure 3: Segmentation of the point cloud using the photogrammetrically achieved surface model (red)

3.3. Data fusion

Within this 3D documentation not only the complementary results of the single-point measurement of the framework and the polygon mesh of the lime tree were combined, but also different data sources. After the photogrammetric evaluation of the dance floor structure the photos are already oriented and georeferenced in the same coordinate frame as the point cloud of the laser scanner. We used the existing stereo pairs for a digital image matching to calculate photogrammetrically derived dense point clouds (figure 4). To condense the incomplete areas of the measured lime tree, no further effort was necessary to collect data. After the fusion of the different point clouds the next step was the calculation of the joint polygon mesh.

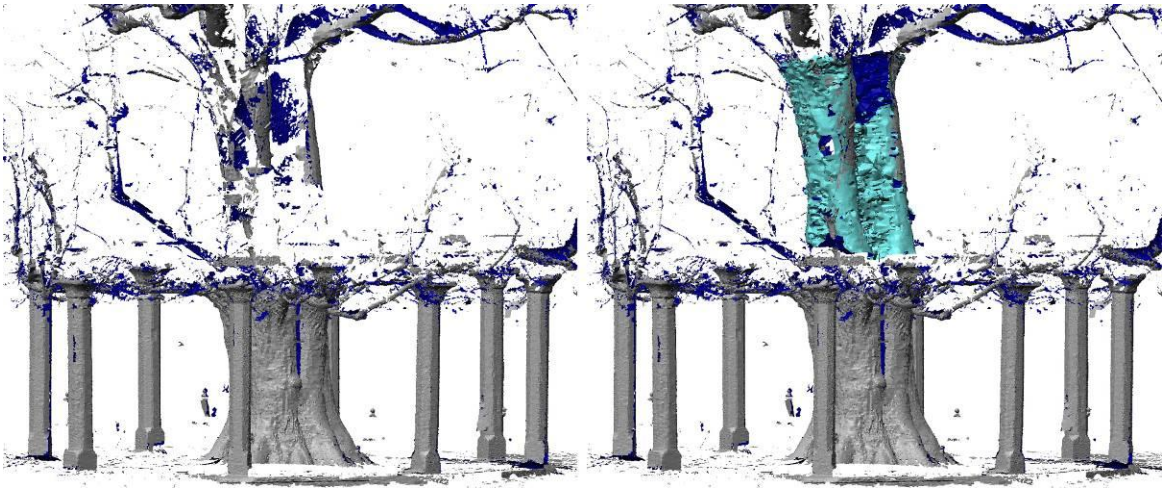

Figure 4: Fusion of the laser scanner point cloud with photogrammetric point cloud (cyan)

4. Results and Perspective

In this practical example the first positive results of an efficient and complementary combination of different recording techniques for the 3D documentation of complex objects was tested (figure 5). Due to a chronological and functional coordination of the used measurement systems, it was possible to significantly reduce the time for data acquisition. A further economisation was achieved by the use of data fusion and combination of different evaluation methods. Another additional benefit was the mutual control of the various data sources. Because of the combined processing of the different data sources within a common coordinate system, errors, deviations and ambiguities in the data set could be detected and eliminated.

Figure 5: Final 3D model of the "Tanzlinde" at Limmersdorf

The next stage will be a jointly discussion between data providers and users concerning the suitability of results for the intended analysis and museum applications. This discussion will be the basis for a rigorous evaluation of this approach for documentation of such complex objects.

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