AUTOMATED DIGITAL RECONSTRUCTION OF TIMBER STRUCTURES FROM POINT CLOUDS

Markus Pöchtrager[a,b], Gudrun Styhler-Aydın[a], Marina Döring-Williams[a], Norbert Pfeifer[b]

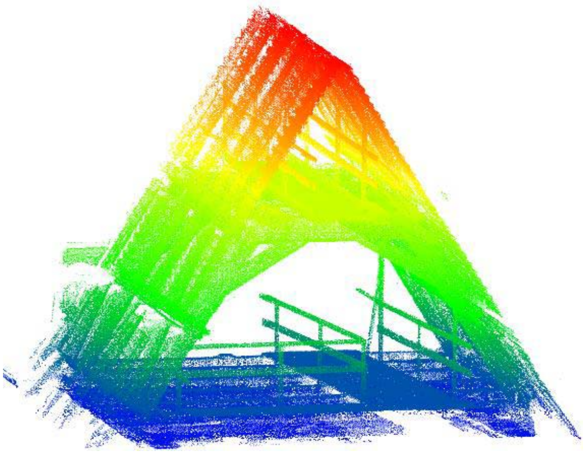
[a] E251 - Institute of History of Art, Building Archaeology and Restoration, TU Wien
[b] E120 - Department of Geodesy and Geoinformation, TU Wien

INTRODUCTION

The analysis of historic timber constructions is an important task for the planning of adaptive reuse of buildings or for maintenance and restoration issues. Current approaches in analysis of timber structures consists of several consecutive stages, including surveying and modelling, that need to be done manually or in semi-automatic routines. A new concept for a fully automated analysis of timber constructions was developed to increase efficiency and put the focus on the data analysis rather than on data processing.

METHOD

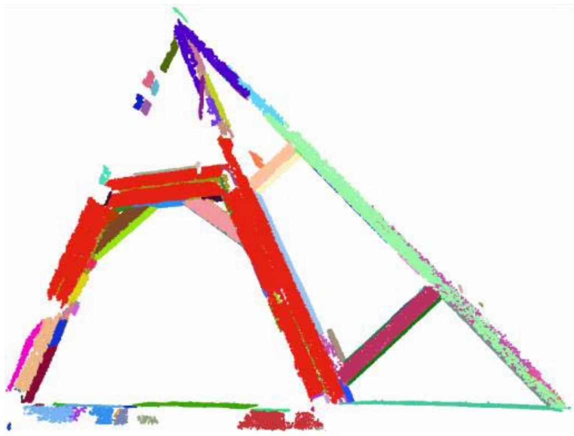
As laser scanner data initially only consists of millions of single points that do not contain much information about the structure of the scanned objects (see Picture 1), we need processing methods that give a link between single points and create connected objects with known geometrical and structural properties.



Picture 1: Point cloud of a historic roof construction in the Vienna Imperial Palace

For an automated modelling of wooden beams with rectangular cross section a workflow was developed, consisting of following stages: 1) Calculate normal vector information for each point, 2) Segmentation of the point cloud, 3) Classify segments and identify beam segments, 4) Identification of adjacent beam segments, 5) Fit cuboids to beams, 6) Intersection of beams and analysis of the structure.

The major tasks in this analysis are the segmentation of the point cloud and subsequently the classification of segments into beam segments and other segments (e.g. walls, roof tiles, etc.). To achieve proper segments of points, representing the faces of the wooden beams, a segmentation is performed using the seeded region growing approach[1] including normal vector information. The angle between normal vectors of neighbouring points is used as a local homogeneity criterion to get segments of flat surfaces. Thereby, two neighbouring points belong to the same segment if the difference between their normal vectors is below a given threshold.

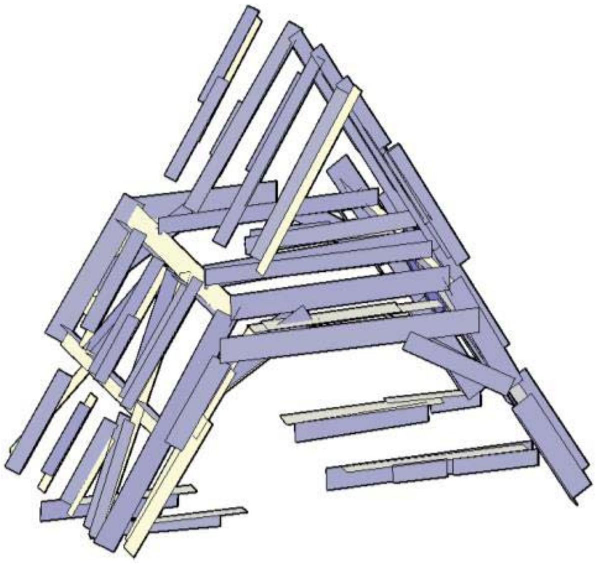


Picture 2: Segmentation results on a roof construction; Different colours represent different segment ids

The classification of segments requires information about two geometric properties of the segment points, namely the planarity and the linearity. As all the beams have a more or less flat surface, only planar segments are taken into account for the further analysis. Non-planar segments are split up using a RANSAC algorithm[2] for plane fitting, if they contain planar sub-segments. In the next step, the 2-D shape of the segments plays a major role in the identification of beam segments. Only segments of linear shape represent a single beam object. To get decisive shape factors the minimum bounded rectangle (MBR) and the α-shape representation can be calculated and used. On the side faces of the beams, where the transition between different beams is smooth enough (see Picture 2 – red segment), the segmentation results in segments containing several beams. A combination of different shape factors indicate to classify the segment as beam segment, discard the segment or to split it into multiple sub-segments again.

Based on the list of classified beam segments, the next step is to detect and join adjacent segments that form a wooden beam together. The association of adjacent planar segments results in a first rough 3-D modelling of the beams (see Picture 3). If at least two sides of a beam are covered by planar segments, it is possible to even go a step further and fit a cuboid to the segment points.

The difficulties in the final processing stage are the modelling of the beams in their correct dimension as well as the detection and modelling of woodworking joints, which are important for structural analysis. The original point cloud can be used as a reference data for the completion of the construction modelling.



Picture 3: Automatically reconstructed beams represented by their planar segments (MBR)

RESULTS AND DISCUSSION

As the results showed, the developed workflow is heavily dependent on the results of the segmentation. The difficulty of finding an optimal homogeneity criterion is caused by cracks and damages in the beams of the historic timber structures. While cracks in the wood should not break up the element into multiple segments, the gap between two wooden elements should be identified as such.

CONCLUSION

As the results in Picture 3 show, the proposed method is feasible for the automated reconstruction of timber structures. A high degree of automation is enabled for the modelling of beams with rectangular cross section. The quality issues regarding segmentation and further processing results in an incomplete automated detection of beams, which in turn requires an intense global analysis of the structure in order to produce a complete documentation of the construction.

REFERENCES

[1] Adams, R., & Bischof, L. (1994). Seeded region growing. *Pattern Analysis and Machine Intelligence, IEEE Transactions on, 16*(6), 641-647.

[2] Fischler, M. A., & Bolles, R. C. (1981). Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography. *Communications of the ACM*, *24*(6), 381-395.