3D LASER SCANNING AND PALEONTOLOGY

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INTRODUCTION

The purpose of this study is to illustrate the potential of 3D laser scanning technology in the context of paleontology. This is demonstrated by addressing a particular research question, the extraction of fossilized oyster shell central lines, in a dataset collected from the world's largest fossilized oyster reef whose age is 16.500.000 years. Laser scanning techniques provide a precise and objective methodology to digitally document and study paleontological objects *in situ* in a non-destructive manner. Analysis of high resolution laser scanning data (1 mm) offers a distinction between geometrical features and therefore supports the interpretation of surrounding topography. The visualization and detection of shell surfaces within the complex surroundings of the oyster reef provide a new room to test and study possibilities of using geometrical features in analysis. The reef's high resolution digital surface model helps to develop new algorithms for object extraction and analysis, such as reliable computations of shell size, orientation and volume. 3D laser scanning is an ideal candidate for multidisciplinary studies. Its results can be combined with those of other disciplines such as photogrammetry, geographic information systems (GIS) or biology and paleontology.

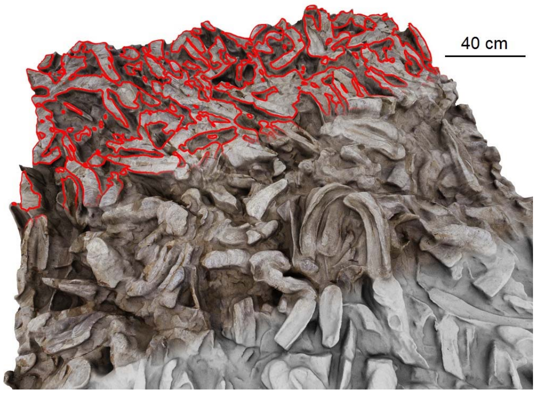
MATERIAL AND METHOD

Data collection

The world's largest fossilized oyster reef is located in Stetten, Lower Austria. A laser scanning and photogrammetric campaign was organized at the reef in 2014. The large and complex site was digitally documented using a remotely controlled high-speed FARO Focus3D laser scanner and a Canon 60D camera with a Canon EF 20 mm f 2.8 lens. The 3D point clouds and high resolution images from this field campaign were processed with photogrammetric methods into a digital surface model (DSM, 1 mm resolution) and orthophoto (0.5 mm resolution) to support the paleontological interpretation of data.

Mathematical method to extract individual 3D central lines of oyster shells: In this study, high resolution orthophoto and the DSM were used to define fossil boundaries. These are then used as an input for an automatic extraction of fossil central lines to provide information of their length. Central line calculation included: i) Constrained Delaunay triangulation between the fossil shell boundary points and formation of the Voronoi diagram; ii) extraction of Voronoi vertices within a shell and construction of a connected graph tree between them; iii) reduction of the graph to the longest possible central line via Dijkstra’s algorithm; iv) extension of longest central line to the shell boundary and smoothing it with a cubic spline curve; and v) integration of the central line into the corresponding 3D point cloud.

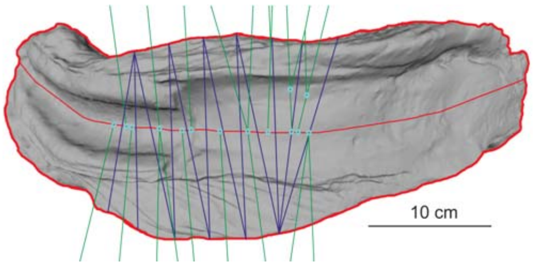
RESULTS AND DISCUSSION



Picture 1: Oblique view of the orthophoto overlain with a shaded digital surface model derived from 3D point cloud (2 m x 1.6 m).

In the test set, 1121 complete oyster shell sizes and their orientation were derived from their 3D central line lengths and attitudes. The largest specimen attains 60.1 cm in length. The mean central-line length is 23.7 cm (σ = 9 cm); the interquartile range is from 17 cm to 30 cm. The orientation data provided direction of shells per tile [1]. Shell volumes were automatically derived from closed mesh models created from 9 individual shells extracted from the reef. These were used as volume estimates for shells with corresponding shell area in the reef as only their upper surface areas were known. Analysed specimens had a mean shell volume of 350.8 cm^3 (σ = 313.7) and age less than 10 years, growing up to about 30 cm in length [2]. Also, our results showed that the automatic central line calculation overestimated the manually collected reference length by 1.5%. This was deemed sufficient for shell age determination and indication of potential hydrodynamic currents. Volume calculations yielded a carbonate production estimate of 15 $kgm^{-2} yr^{-1}$.

CONCLUSION



Picture 2: High-resolution 3D model of single oyster shell overlapped with illustration of Delaunay triangulation, Voronoi vertices and extracted central line.

The resulting longest path estimate for the 3D central line is a size parameter that can be applied in oyster shell age determination both in paleontological and biological applications [2]. Our investigation evaluated that the proposed method was successful in measuring shell lengths based on a comparison between automatically extracted central lines and manually collected reference data.

Despite the numerous publications that deal with the lower Miocene strata of the investigation area, virtually nothing was known about the geometry of the shell bed. This study provided a novel paleontological context about size, orientation, and volume of the fossil shells which are now included in a GIS database. Moreover, extracted central lines support 3D object matching by finding similar or identical objects in the database. In future, our work will aim to use point cloud and central line information to better describe relations between them in order to find shell pairs. These will provide a digital documentation of the current status of the fossils. Considering the case of natural disasters or deliberate destruction, the highly detailed digital model enables future interpretation and analysis based on not yet known scientific experiences.

REFERENCES

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[2] Harzhauser, M., Djuricic, A., Mandic, O., Neubauer, T. A., Zuschin, M., and Pfeifer, N.: Age structure, carbonate production and shell loss rate in an Early Miocene reef of the giant oyster Crassostrea gryphoides, Biogeosciences, 13, 1223-123, 2016.