GIS database for the World's largest fossil oyster reef

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Abstract

We present the first GIS database as an interface of a digital oyster reef and managing tool for a protected natural heritage site. The state of the art in 3D digitizing, data processing, and visualization technologies allows mapping of the world's largest fossil oyster reef in order to support paleontological investigations of the about 16.5 million years old site. This study is making an evaluation of a large area economically feasible in both time and costs. The reef layer was determined using 3D point measurement method (terrestrial laser scanning). It derived high resolution data of about 150 points per square centimeter with measurement speed up to 1 million points per second. Those points are used to create 1mm digital surface model (DSM) of entire oyster reef. The texture is assigned to the DSM for more realistic visualization resulting in high spatial resolution (0.5mm/px) orthophoto. The aim is to replace the manual survey made in situ and enable the palaeontologist to benefit using those kind of representations. Interpretations of the digital data are based on a data base containing spatial and non-spatial aspects such as shell size, orientation, position, species, state of fragmentation, etc. DSM and orthophoto visualizations are significantly supported by GIS tools providing various possibilities to design required thematic maps and link each individual shell with their descriptive attributes.

Keywords: terrestrial laser scanning (TLS); 1mm digital surface model; 0.5mm orthophoto; mapping fossils; GIS database; oyster reef.

1 Introduction

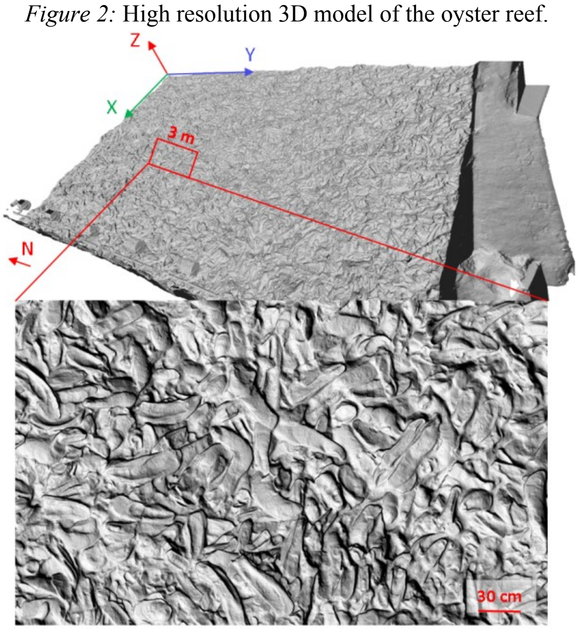
Recent advances in technology have revolutionized the acquisition of geological surfaces and especially fossilized sites, offering new perspectives on the structure and morphology of their typically irregular surface [1, 2, 3]. These developments have impact on paleontological science, creating a step change in the resolution, dimensionality and precision of surface models, in our study an oyster reef (Fig. 1).

Figure 1: Excavation of the fossil oyster reef in 2005

2 Survey method

The survey method included close range photogrammetry and terrestrial laser scanning (TLS), which provide 3D point cloud data capturing details of more than 50 000 fossil shells on 459 m^2. Figure 2 shows 3D oyster reef and one tile (2x3 m).

Figure 2: High resolution 3D model of the oyster reef.



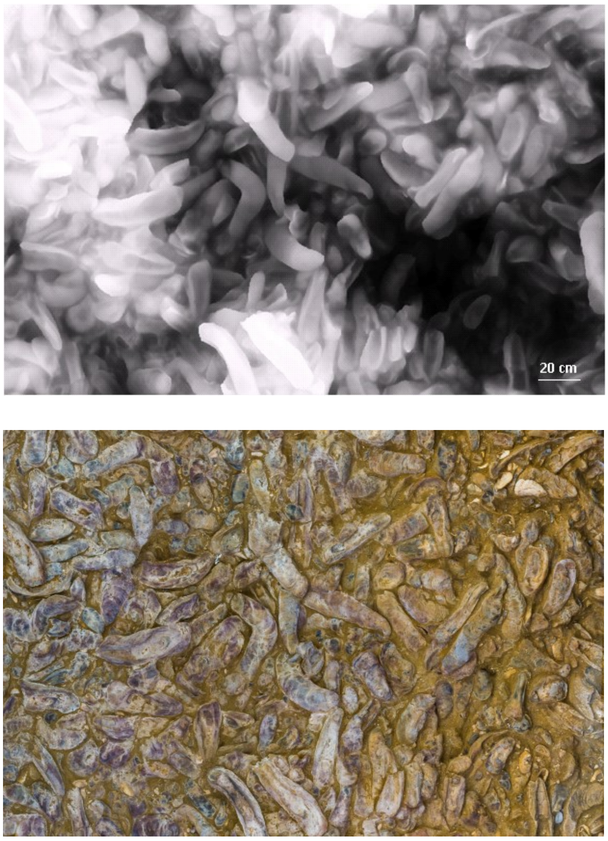
Direct in-site measurements are impossible because the site is protected, but remote digital documentation supports research on this unique site. In total, 83 scan positions were enough to collect data covering the entire reef. From all those stand points around 1 billion points were acquired at the site. The large data volume required piece-wise processing of the data. Therefore, the data were organized in 81 rectangular tiles. The tiles were defined with an extension of 2.1 m (East/West) by 3.1 m (North/South).

3 Results

3.1 3D Digitizing

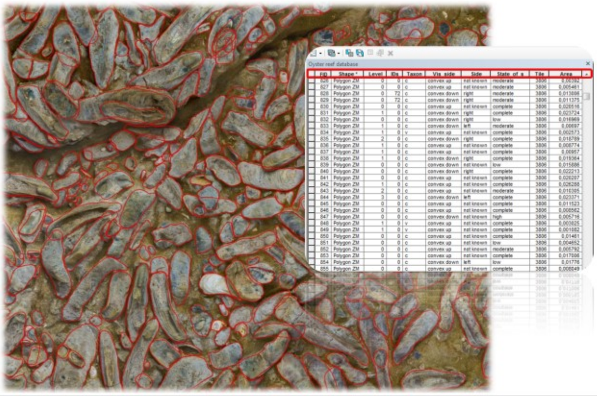
From laser scanning a 1mm grid width digital surface model (Fig. 3) was determined based on the highest points from TLS data. The photos were combined with an orthophoto mosaic with 0.5mm pixel size (Fig. 3). Both, the high-resolution surface model and its texture are important components for further geological interpretation and paleontological reconstruction of different shell species ranging in length from a few centimetres up to 60 cm.

Figure 3: (Top) 1mm digital surface model; (Bottom) 0.5mm orthophoto (2x3 m).



Interpretations, in form of shell outlines, are stored in a GIS-database with a data structure enabling fast access despite the large data volume and ensuring a consistent repository for the researchers involved. The GIS database has numerical and descriptive elements. Numerical attributes are identity (ID), level of overlap, length (2D and 3D), orientation (yaw, pitch, and roll angle), and descriptive attributes are taxon (7 different species), side of the shell (left, right, unknown), state of specimen (complete, fragmented, not determined), shell position (convex up, convex down), area, etc. An example of data structure is illustrated in Figure 4 and the list of database attributes, their data type, range of values, unit and more detail explanation are presented in Table 1.

Figure 4: (Left) Example of individual fossil outlines; (Right) Overview of the oyster reef database attributes.



The derived data (e.g. attributive data) enables different spatial data queries such as encrustation by oysters, taphonomic map, distribution of left and right shells, distribution of convex up and convex down shells, distance maps or other specific thematic maps for geological purposes. The GIS database also allows you to define additional attributes in the future if required, such as geological features: abrasion or bioerosion (0–no, 1-present a bit, 2–strong), covered by sediment (yes/no), encrustration by barnacles or another oyster (yes/no).

Figure 5: Example of thematic map: distribution of left and right shells (3x2 m); (Background layer) transparent orthophoto overlapping shaded digital surface model.

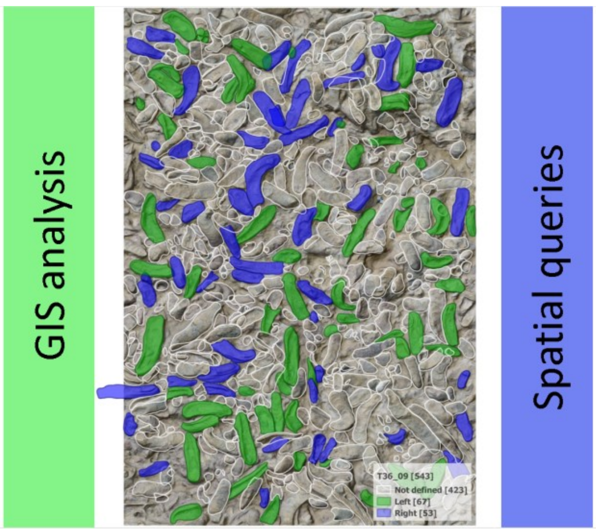


Table 1: The list of database attributes, their data type, range of values and unit.

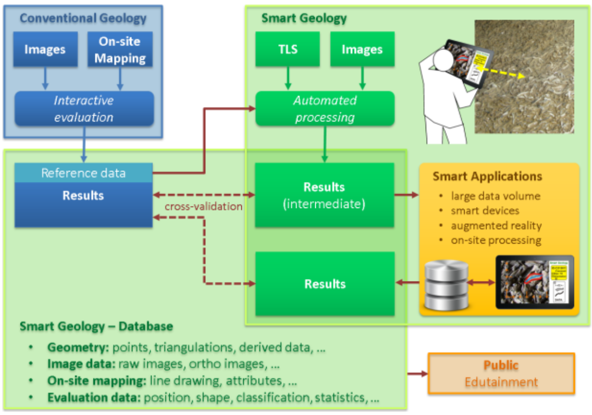
Name of attribute	Data type	Range of values	Unit	Additional explanation
ID	integer	2 bytes, positive numbers	/	Number of fragments expected to reach: 2^16~65536
Level	integer	3 bit, positive numbers	/	Number of overlaps that can occur on the reef 1, 2, 3, 4, etc.
ID secondary (IDs)	integer	2 bytes, positive numbers	/	IDs contains a possible pair of broken shell.
Taxon	text (length 30)	Key list: i) Crassostrea gryphoides ii) Ostrea digitalina iii) Pecten. iv) Venerupis v) Perna vi) Gastropod vii) Fragment - unknown	/	Presents the name of a species, mostly oysters (i and ii), but database contains other species as well (iii-vii).
Position	text	Key list: i) interior – convex down ii) exterior – convex up iii) unknown	/	Applies only to oysters.
Side	text	Key list: i) left ii) right iii) unknown	/	It does not apply to all specimen but only to oysters.
State of specimen	text	Key list: i) high fragmented ii) moderate iii) low iv) complete shell	/	Presents the stage of fragmentation.
Length 2D	decimal number, precision 4, scale 2	Positive numbers	cm	The 2D length is measured along the specimen based on projected shell outline.
Length 3D	decimal number, precision 4, scale 2	Positive numbers	cm	The 3D length is measured along the specimen including surface curves and roughness.
Area	decimal number, precision 4, scale 2	Positive numbers	cm^2	Area is calculated based on shell polygon defined by shell boundary.
Yaw angle *(normal axis)*	decimal number, precision 4, scale 2	Range from 0-180 clockwise from north (0) to south (180)	º	Yaw axis presents an axis drawn vertically in respect to shell top surface, and it is perpendicular to the other two axes.
Pitch angle *(lateral axis)*	decimal number, precision 4, scale 2	Range from -90 to +90 where 0 = horizon, +90 = straight up and –90 = straight down	º	Pitch axis is an axis running from the left to right side of commissure plane, and goes along the shell width.
Roll angle *(longitudinal axis)*	decimal number, precision 4, scale 2	Range from -90 to +90 where 0 = horizon, +90 = full roll right and –90 = full roll left	º	Roll axis is defined as an axis drawn through the body of the shell from oyster hinge to the distal shell margin.

3.2 Smart technologies

The visualization method such as colour shaded reef and corresponding legend (Fig. 5) help to understand, identify and explore huge amount of data. Integration of smart devices (e.g. TabletPCs) and GIS interface improve the efficiency and quality of paleontological interpretation by making data and results available at any place enabling on-site accessibility of all project data as well as on-site data evaluation considering already available digital information [4].

Furthermore, "smart geology" technologies include, beside a huge amount of data, an interactive presentation of individual 3D fossil presented using 4D-Reality, a virtual-reality application for high-resolution presentation and analysis of 3D-objects [see 5] and Fig. 7.

Figure 6: Workflow diagram showing the "Smart Approach" proposed for highly automated processing and evaluation (right), and the conventional approach (left) for evaluating and validating the results of the smart approach.



The application (Fig. 7) has been optimized to run on mobile devices, PCs or internet browser which support WebGL. Its purpose is to entertain end-users by taking into account the principle of virtual museums - learning through playing and involving interaction experience.

Figure 7: Demonstration of Oyster Virtual App

4 Conclusion

TLS has the potential to provide a high resolution digital surface model of a fossil oyster reef and orthophoto enough detail to depict individual oyster shells and even small-scale forms such as various gastropod and bivalve species (a few cm diameter). The aim is to make them available through GIS database for the geotainment-park and museum of natural history for visitors in order to have the opportunity to search, zoom and study a virtual oyster reef, query spatial data for analyses and visualize spatial layers. Furthermore, a benefit of the GIS database for paleontological experts is that provides a digital documentation of the current status of the whole oyster reef where information is displayed on interactive maps. The usage of map layers which contain different information about the mapped area makes GIS an ideal candidate for interpretative mapping and outlining of small objects such as fossil shells. Moreover, GIS is also contributing in multidisciplinary investigations, combining its advantages with other disciplines such as laser scanning and photogrammetry, cartography, geology, concerning both spatial and non-spatial aspects.

An extension to our work will be to introduce more attributes which are significant for palaeontologists to analyse for instance bioerosion and abrasion on the shells. New attributes and their relationships will be followed by creation of new thematic maps and possibilities to extract additional information about the world's largest fossil oyster reef.

Acknowledgement

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