Making a 3D model of human skulls with optical scan

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Introduction

When analyzing an ancient skull researchers often have difficulties measuring morphological properties mainly due to the curvature of the skull.
By having the skull as a 3D model researchers can do measuring exact or as close to exact without damaging the skulls in any way.

This project is about showing that it is possible to construct a 3D surface with structured light vision of a real human skull.
The optical scanner returns a point cloud, where some processing is necessary in order to get a clean point cloud surface that can be used for generating a 3D surface mesh.

Test objects

The skulls are from the P. W. Lunds collection of artifacts from Lagoa Santa in Brazil. The skulls are very fragile and therefore have to be handled with care and away from damaging light. This is one of the reasons that optical scanning is more optimal than CT scanning.
The skulls are up to 10.000 years old and are some of the oldest skulls from South America[1].

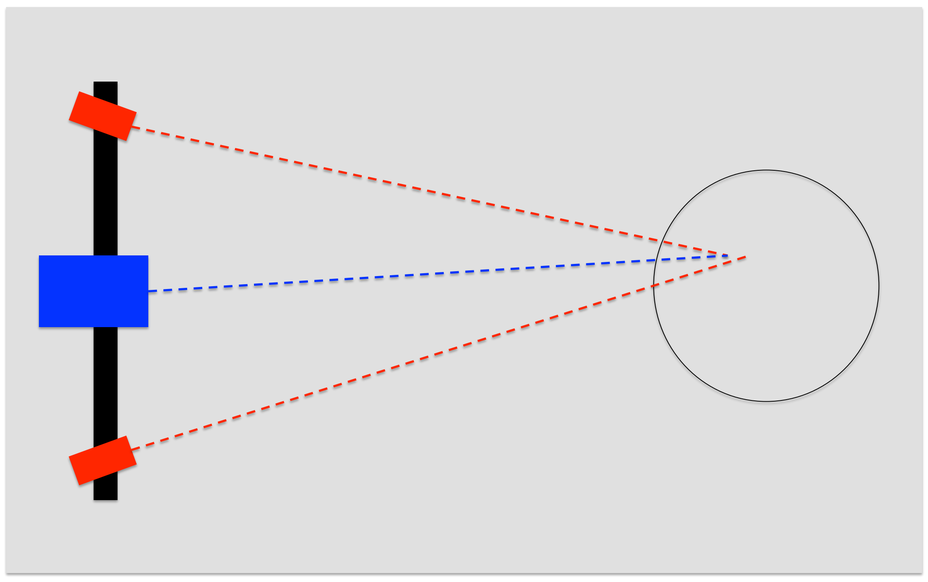
Some of the skulls that was scanned.

A closeup of the skull ZMK-1-1845-15113.

Pipeline of the work

Optical scanning

Here is a quick overview of the optical scanner using structured light.
- The projector projects a pattern.
- Both cameras capture the reflection of the projected patterns.
- From the projected pattern and the camera geometry it is possible to find depth coordinates of the object.
- Collect an entire 360° scan.

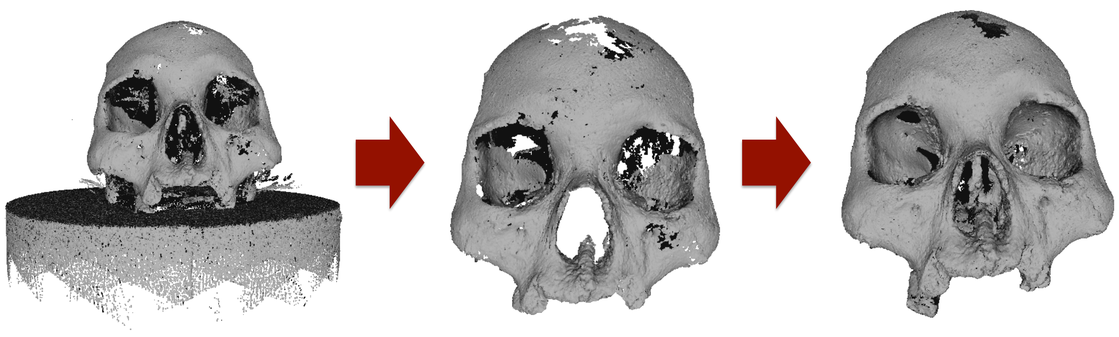


Model of the scanner. The two red rectangles are the cameras, the blue one is the projector and the circle is the rotation stage to turn the object.

Cleaning and aligning the point clouds

The point clouds have been made but is still noisy and is not a complete scan.
Cleaning:
- Remove unnecessary items, the foam under the skull.
- Remove outliers by nearest neighbor search.

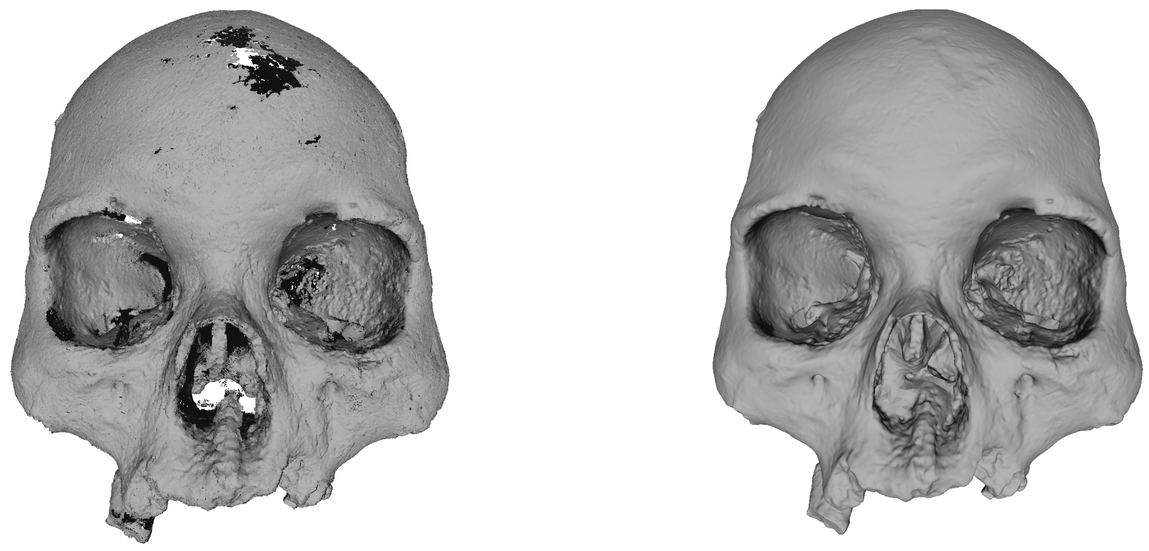
Alignment of scans:
- Manual alignment.
- Automatic alignment by Iterative Closest Point(ICP).



The process for ZMK-1-1845-15113. From left, the scanned upright skull with a foam ring and a lot of noise. The middle, the upright skull cleaned. The right, clean and aligned point cloud.

Point cloud to mesh

The process going from point cloud to mesh is as following for Poisson reconstruction.
- Centroid vertex found for *k* nearest neighbor and normals estimated.
- Riemannian graph created to find the edge to every *k* nearest neighbor.
- Using minimum spanning tree to make the final mesh.



The skull of ZMK-1-1845-15113 as point cloud, left, and as a mesh, right. As it can be seen the Poisson algorithm have reconstructed the missing parts.

Results

The primary objective of the study is to show that optical scanning is most certainly a viable alternative to measurements by hand.
Here is a comparison of ZMK-1-1845-15113 or SH 04 [1].

Measuring method	Measured by hand [1]	3D mesh measured
GOL	182mm	181.98mm
NOL	179mm	178.97mm
BBH	137mm	137.67mm
BNL	102mm	101.76mm

Just by the results above it is fair to say that measuring a mesh from optical scan is just as accurate and exact as hand measuring. The reconstructed meshesare also quite nice and accurate looking at which is also an important fact when scanning the skulls.

References

[1]: W. A. Neves, M. Hubbe, L. B. Piló, May 2005, Early Holocene human skeletal remains from Sumidouro Cave, Lagoa Santa, Brazil: History of discoveries, geological and chronological context, and comparative cranial morphology

Acknowledgements

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