Landmarks measurement on grey seal skulls using a SeeMaLab structured light 3D scanner and MicroScribe 3D digitizer

D. Messer, M. Svendsen, V. A. Dahl, K. Conradsen, A. B. Dahl, A. Galatius, M. T. Olsen
DTU Compute & Natural History Museum of Denmark & Aarhus University

Context and Purpose

Both 3D digitizer arms and structured light surface scanners are portable, easy to use, and relatively cheap. While digitizer arms have been the "gold standard", benefits of having full 3D models are manifold. We assess the measurement error associated with the use of a high-resolution structured light scanner built at DTU Compute for the reconstruction of 3D digital models of grey seal skulls, and compare our setup to a popular digitizer arm.

Data Collection

The data collection is based on 22 complete **skulls of grey seal** (*Halichoerus Grypus*). Each skull was captured twice with a structured light surface scanner, resulting in a 3D digital model. The final data set consists of 31 fixed **anatomical landmarks**, which were independently measured twice by two operators both on the 3D digital models, and directly on the skulls using a Microscribe 3D digitizer.

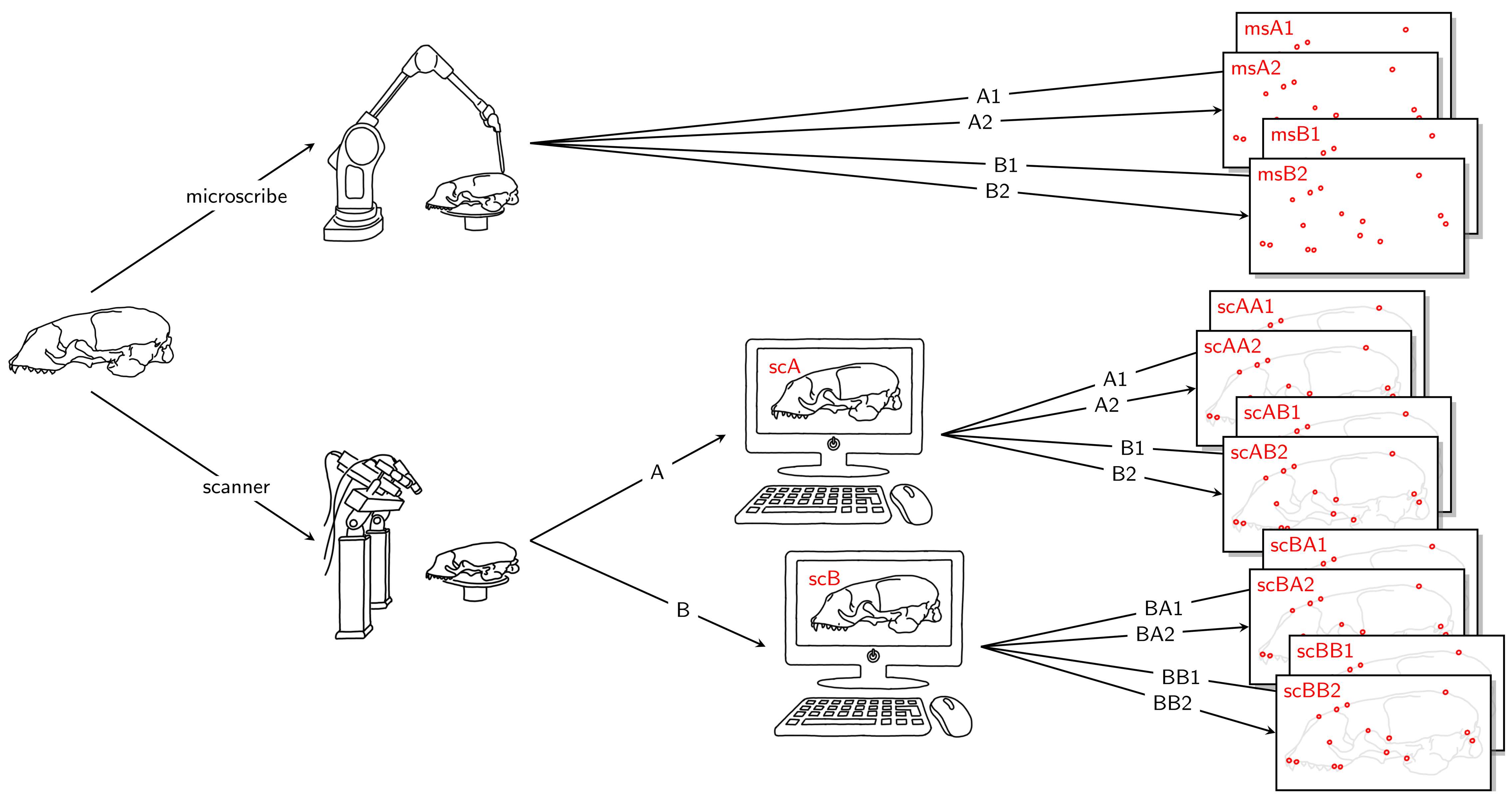

Figure 1: Pipeline for a given skull. Twelve sets of 31 landmark coordinates were measured per skull, which results in an overall data set of 264 landmark configurations.

Methods

1) **Procrustes ANOVAs** on skull shape and size: Quantify the measurement error of our setup
2) **Repeatability** of the two measurement methods: Quantify the measurement error in repeated measures design
3) **PCA** separately for both methods: Similar patterns of variation among specimens? ✓
4) Analysis of **inter-landmark distances**: Systematic differences between the two measurement setups? ✗ Analyse reliability of landmark placing.

1) Procrustes ANOVA

Variables	Df	SS	MS	Rsq	Pr(>F)
All coordinate sets					
Individual	21	0.927	0.044	0.926	0.001
Method	1	0.005	0.005	0.005	0.001
Operator	1	0.006	0.006	0.006	0.001
Method:RepScan	1	0.001	0.001	0.001	0.001
Residuals	239	0.060	0.000	0.060	
Total	263	1.001			
Scanner-based coordinate sets					
Individual	21	0.628	0.030	0.951	0.001
Operator	1	0.006	0.006	0.008	0.001
RepScan	1	0.001	0.001	0.001	0.001
Residuals	152	0.026	0.000	0.040	
Total	175	0.660			
Digitizer-based coordinate sets					
Individual	21	0.315	0.015	0.942	0.001
Operator	1	0.004	0.004	0.011	0.001
Residuals	65	0.016	0.000	0.047	
Total	87	0.334			

Table 1: Procrustes ANOVA on shape for the full dataset and different subsets. The R-squared values (Rsq) give an estimate of the **relative contribution of each factor to the total shape variation**.

2) Repeatability

Variables	Df	SS	MS	Rsq	Rep
Scanner-based coordinate sets, scanned by operator A					
Individual	21	0.320	0.015	0.958	0.985
Individual:RepLM	22	0.003	0.000	0.008	
Residuals	44	0.011	0.000	0.034	
Total	87	0.334			
Scanner-based coordinate sets, scanned by operator B					
Individual	21	0.312	0.015	0.959	0.984
Individual:RepLM	22	0.003	0.000	0.008	
Residuals	44	0.011	0.000	0.033	
Total	87	0.326			
Digitizer-based coordinate sets					
Individual	21	0.315	0.015	0.942	0.989
Individual:RepLM	22	0.002	0.000	0.006	
Residuals	44	0.018	0.000	0.052	
Total	87	0.334			

Table 2: Landmarking error, and **repeatability (rep) for replicas**. Procrustes ANOVA on shape for scanner-based datasets and digitizer-based dataset.

Conclusions

1) Total shape variation is mainly due to **differences between individuals** (Table 1).
2) **Repeatability for replicas is high**, and similar for both measurement methods (Table 2).
3) We find **similar patterns of variation among specimens** when conducting a PCA separately for both measurement methods.
4) Evidence for some **systematic differences** between inter-landmark distances measured on the 3d models, and measured directly on the skulls.
   Type I landmarks (e.g. ridges) are more difficult to place on 3D models of smaller skulls.

Future Research (Ongoing)

Analysis of shape differences of 95 grey seal skulls collected from three different populations, but only two distinct, scientifically recognized subspecies. We aim to **re-evaluate the hypothesis of three distinct subspecies** by means of

- Geometric morphometrics on landmark coordinates measured on 3d models
- **Statistical shape analysis** using the whole 3d model