

PP-04

CT 영상 데이터를 통한 두개골 변이 학습

(Learning Skull Shape Variations through CT Scan Data)



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Purpose: To develop and validate a parametric three-dimensional (3D) skull model capable of predicting subject-specific skull geometry from a single RGB image without requiring computed tomography (CT) imaging, thereby reducing radiation exposure while maintaining anatomical plausibility.

Methods: Ninety-seven paired RGB-CT datasets were collected from a university hospital. To overcome limited data availability, 81 synthetic skull CT volumes were generated using 3DMedDiffusion and incorporated into the statistical shape prior. All skulls were registered to a common template using iterative closest point alignment, and principal component analysis was performed to construct 50 skull-specific blendshapes. Skull shape parameters were recovered in closed form from CT-derived meshes. A regression network was then trained to map FLAME facial shape parameters, extracted from RGB images, to skull shape parameters. Reconstruction accuracy was evaluated on a held-out test set using Chamfer distance.

Results: On the test set, the predicted skull achieved a mean Chamfer distance of 0.24 mm, outperforming the template skull (0.78 mm) and the dataset average skull (0.26 mm). Compared with a full-body skeletal baseline, our approach demonstrated superior skull-specific geometric representation. Synthetic augmentation improved surface smoothness, reduced reconstruction noise, and enhanced anatomical variability without additional clinical annotation.

Conclusion: Monocular RGB images can be used to infer anatomically plausible 3D skull geometry. The proposed parametric skull model provides a scalable and reproducible framework that may

serve as a complementary tool for craniofacial visualization, surgical planning support, and computer-assisted aesthetic analysis.

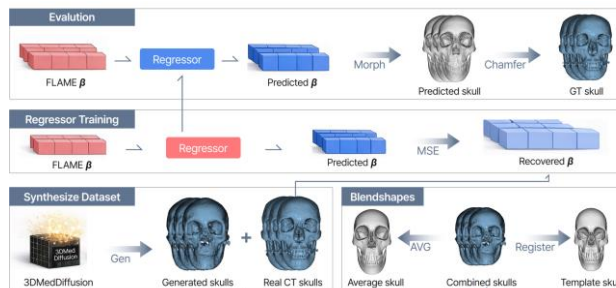


Figure 1. Overview of the proposed pipeline.

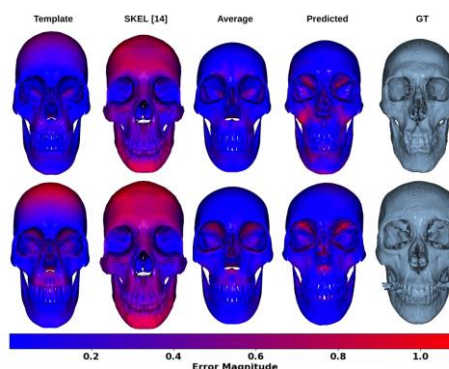


Figure 2. Error maps comparing each skull to its corresponding ground truth (GT). Blue indicates low error, while red denotes high error.

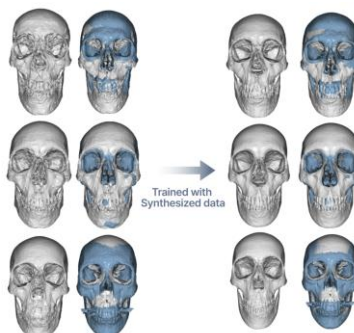


Figure 3. Left: Skulls generated using the regressed shape parameters β_S without incorporating synthesized samples into the shape prior, shown after alignment with the ground truth skulls. Right: Skulls generated using β_S learned with shape priors made with synthesized samples, also shown after alignment with the ground truth skulls.

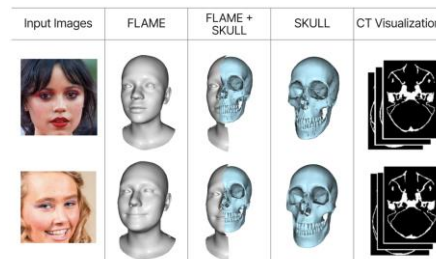


Figure 4. Examples of 3D skull reconstruction from a monocular image using the proposed method