ENGLISH

Topic/Title

Development of AI-Driven Methods for Geometric Morphometrics

Proposer (Tutor)

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Research proposal[1]

Geometric morphometrics is a powerful quantitative approach used across various scientific disciplines, including evolutionary biology, anthropology, and medicine, to study shape variation and its underlying causes. It relies on the precise capture and analysis of landmark and semilandmark coordinates on biological forms. While traditional methods have significantly advanced our understanding of shape, challenges persist in the accurate and efficient reconstruction of complex 3D surfaces and the inference of complete shapes from partial remains. Current techniques for 3D surface reconstruction, such as the ball pivoting algorithm, can be computationally intensive and sensitive to data quality, often requiring complete and dense landmark data. Furthermore, the reconstruction of soft tissue head shapes from skeletal cranial remains a complex and often subjective process with little to no scientific validation.

Despite the recent advancements in 3D scanning and data acquisition, the conversion of raw scan data into analyzable geometric morphometric datasets still faces limitations. The current reliance on algorithms like ball pivoting for surface reconstruction can be inefficient, particularly when dealing with noisy or incomplete data, and does not inherently leverage the vast amount of shape

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information contained within existing morphological datasets. Simultaneously, the prediction of an individual's full head shape from fragmented or partial cranial remains, a crucial task in forensic anthropology and paleontology, largely depends on laborious manual techniques or statistical averages that may lack the individual-specific nuance required for high-fidelity reconstructions. There is a pressing need for more robust, automated, and intelligent methods that can infer and reconstruct shapes with greater accuracy and efficiency.

The research will focus on two primary objectives,

1. AI-driven Shape Reconstruction from Inferred Landmark and Semilandmark Positions: This objective aims to develop an AI model capable of inferring the precise 3D coordinates of landmarks and dense semilandmarks from point cloud data or even incomplete scans. The proposed AI-driven approach will learn complex anatomical relationships from large datasets of known shapes, allowing it to predict and reconstruct complete or partial surfaces more accurately than conventional methods. Specifically, this method will investigate deep learning architectures, such as PointNet or graph neural networks, to directly process raw landmark data. The goal is to move beyond the limitations of algorithms like ball pivoting by leveraging the learned contextual information about shape variability, thereby enabling robust shape reconstruction even with sparse or noisy input data.

2. Machine Learning for Head Shape Development from Cranial Remains: This objective will explore and develop machine learning algorithms for the automated reconstruction and prediction of full soft tissue head shapes from skeletal cranial remains. Leveraging advancements in 3D imaging of skulls and corresponding soft tissue data, the project will train sophisticated ML models (e.g., convolutional neural networks, generative adversarial networks, or transformer-based architectures) to map the intricate relationship between cranial bone morphology

and external facial features. The developed algorithm will learn to generate plausible and anatomically accurate head shapes, offering a significant improvement over existing statistical or artistic reconstruction methods by providing a data-driven and potentially more individualized approach. This will have profound implications for forensic identification, paleoanthropological reconstructions, and medical applications.

This research is anticipated to yield innovative AI frameworks that significantly enhance the capabilities of geometric morphometrics. The successful development of AI-driven shape reconstruction methods will provide a more efficient and accurate alternative to existing algorithms, facilitating large-scale morphological studies. Furthermore, the machine learning algorithm for head shape development from cranial remains will offer a groundbreaking tool for forensic science and anthropological research, enabling more reliable and precise facial approximations. The project will contribute to the interdisciplinary field of AI in science, demonstrating the transformative potential of machine intelligence in deciphering complex biological shapes.

Research program

1st Year

- ***1. Acquisition of basic knowledge of neural networks and deep learning***
- ***2. CNN, GAN, PointNet algorithms***
- ***3. Geometric morphometry algorithms***

2nd Year

- ***1. Application of Graph Neural Network for 3D mesh reconstruction.***
- ***2. Development of machine learning for soft tissue reconstruction***

3rd Year

1. ***Application of machine learning for soft tissue reconstruction***

2. ***Overall estimation of models***

3. ***Thesis writing***