AI-driven 3D architectural and structural analysis by multiple-staged deep reinforcement learning

Authors :

Sang-Hwy Lee[a], Sung Ho Kang[b], Kiwan Jeon[b], Pierre Corre[c], Jean-Philippe Perrin[c]

Institutions :

a. Department of Oral and Maxillofacial Surgery, Oral Science Research Center, College of Dentistry, Yonsei University, Seoul, Republic of Korea

b. Division of Medical Mathematics, National Institute of Mathematical Science, Daejeon, Republic of Korea.

c. Department of Maxillofacial Surgery and Stomatology, University Hospital, Nantes, France

Abstract :

The architectural and structural craniofacial analysis of the late Professor Delaire is an outstanding and unique system for the evaluation of the mutual balance between the face and cranium on an individual basis. Recent advances have led to the transition from original two-dimensional (2D) cephalometrics through three-dimensional (3D) analysis to automatic 3D cephalometrics. However, the lengthy time needed for manual landmarking as well as other factors have delayed the widespread adoption of 3D cephalometry. We here want to present our automatic 3D cephalometric annotation

system based on multi-stage deep reinforcement learning (DRL) and volume-rendered imaging. This system considers geometrical characteristics of landmarks and simulates the sequential decision process underlying human professional landmarking patterns. It consists mainly of constructing an appropriate two-dimensional cutaway or 3D model view, then implementing single-stage DRL with gradient-based boundary estimation or multi-stage DRL to dictate the 3D coordinates of target landmarks.

This system clearly showed sufficient detection accuracy and stability for direct clinical applications, with a low level of detection error and low inter-individual variation (1.96 ± 0.78 mm). Our system, moreover, requires no additional steps of segmentation and 3D mesh-object construction for landmark detection. The system also provided the excellent detection accuracy and stability for the clinical data.

We believe these system features will enable fast-track cephalometric analysis and planning, even for the direct clinical applications, and expect it to achieve greater accuracy as larger CT datasets become available for training and testing.