A Data-Driven Pipeline for Smartphone-Based Photogrammetric 3D Foot Reconstruction

Liangliang Xiang[1,2], Justin Fernandez[2], Yaodong Gu[3], Zixiang Gao[4], Ruoli Wang[1], Elena Gutierrez-Farewik[1,5]
[1] KTH MoveAbility Lab, Dept. Engineering Mechanics, KTH Royal Institute of Technology, Stockholm, Sweden
[2] Auckland Bioengineering Institute, University of Auckland, Auckland, New Zealand
[3] Faculty of Sports Science, Ningbo University, Ningbo, China
[4] Faculty of Kinesiology, University of Calgary, Calgary, Canada
[5] Department of Women's and Children's Health, Karolinska Institute, Stockholm, Sweden
Email: lxia467@aucklanduni.ac.nz

Summary

This study presents a data-driven pipeline for 3D foot-ankle reconstruction using smartphone-based photogrammetry. Three reconstruction methods—Android and iPhone LiDAR-based photogrammetry, and PC-based photogrammetry—were evaluated. Model accuracy was validated against a 3D optical foot scanner. The results demonstrate the feasibility of smartphone photogrammetry for precise and accessible foot modeling in biomechanics research.

Introduction

Reconstructing 3D models of the foot and ankle holds significant potential for analyzing biomechanics and conducting stress-strain simulations—key techniques in rehabilitation and sports injury prevention. However, conventional methods rely on costly and impractical imaging modalities, such as CT or MRI [1]. Photogrammetry offers a more accessible alternative, commonly used for 3D object reconstruction in fields like archaeology and geoinformatics [2]. Recent advancements in data-driven approaches, including machine learning and shape morphing, have enabled foot reconstruction from optical scan data [3]. However, these methods typically require specialized optical scanning devices, limiting their practicality. This study aims to democratize 3D foot modeling by leveraging smartphone photogrammetry, thus expanding its usability in clinical and research applications.

Methods

Eight able-bodied participants (age: 26.8 ± 1.7 years, height: 1.78 ± 0.04 m, mass: 73 ± 6.5 kg) were recruited for right foot scans using a 3D optical foot scanner and smartphone cameras, with ethical approval. Participants were free from pes planus, pes cavus, or other foot deformities. Foot surface scans were conducted under weight-bearing conditions using the Easy-Foot-Scan machine (OrthoBaltic, Lithuania). Sixty photos were captured with a OnePlus 9RT smartphone (50 MP, Sony IMX766) and an iPhone 16 Pro equipped with a Light Detection and Ranging (LiDAR) sensor (48 MP, Sony IMX903). Three reconstruction methods were tested and compared with models generated from the optical foot scan machine, validated in a previous study [3]. Specifically, photographs taken with the Android phone were processed using the Polycam mobile application (Polycam Inc.) and Agisoft Metashape software (v2.1.3, Agisoft LLC) on a PC to generate 3D reconstruction from photogrammetric point clouds. The iPhone camera, combined with photogrammetry and LiDAR, was used with Reality Composer (Apple Inc.) for 3D scanning. Model accuracy was evaluated using Root Mean Square Error (RMSE), Dice Similarity Coefficient (DICE), and Hausdorff distance.

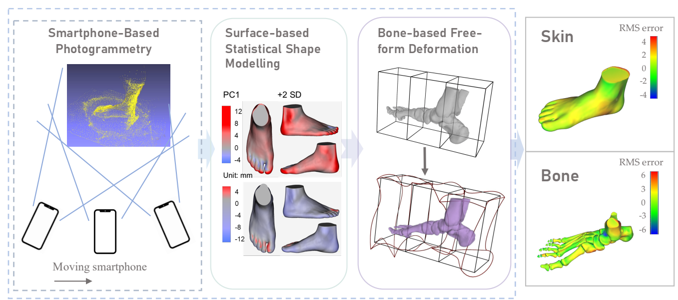

Figure 1: The pipeline used for reconstructing the 3D foot model.

Results and Discussion

The DICE, RMSE, and Hausdorff distance for smartphone photogrammetry-based models with LiDAR sensors were 0.94 ± 0.01, 2.29 ± 0.32 mm, and 1.59 ± 0.19 mm, respectively, compared to the optical foot scan. These results demonstrate that smartphone photogrammetry, including both Android and iPhone LiDAR-enhanced methods, produces models with accuracy comparable to the optical foot scanner, with minimal deviations in surface detail. This suggests that smartphone-based photogrammetry, particularly when paired with LiDAR, is a viable and accessible alternative for 3D foot reconstruction in clinical and research settings.

Conclusions

This study presents a subject-specific foot surface reconstruction method using smartphone photogrammetry. The resulting foot models can be further refined through statistical shape modeling for surface generation and bone reconstruction using free-form deformation [3]. The proposed workflow enables the accurate creation of foot models informed by population-level anatomical data, enhancing the potential for biomechanical simulation investigations.

References

[1] Florkow MC et al. (2022). *J. Magn. Reson. Imaging*, **56**: 11-34.
[2] Fang K et al. (2023) *Measurement*, **223**: 113764.
[3] Xiang L et al. (2024). *J. Biomech.*, **168**: 112120.