3DDX: Bone Surface Reconstruction from a Single Standard-Geometry Radiograph vis Dual-Face Depth Estimation

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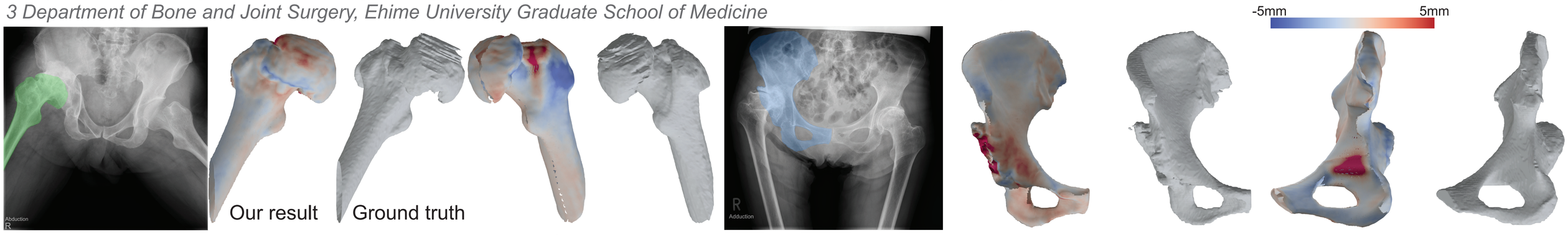


Visualization of accurate 3D reconstruction by our method for two severely diseased patients.

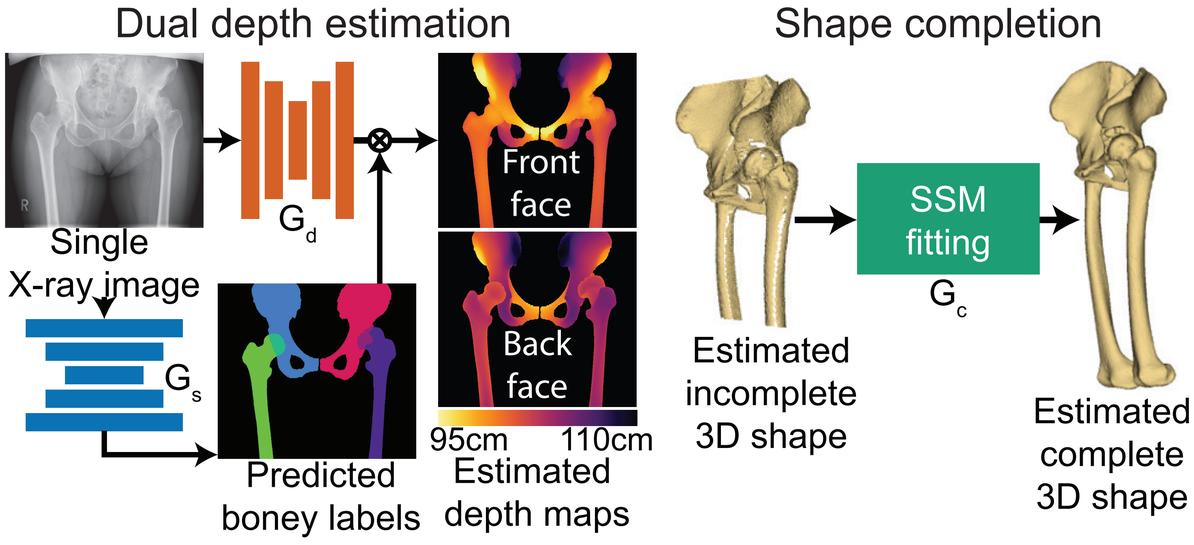
Introduction

Monocular 3D reconsturction is a **long-standing challenge**.
Existing works suffer from **low accuracy and low efficiency**.
Depth estimation from an X-ray image has been **barely explored**.

Contributions:

- Novel **framework for 3D reconstuction** using depth estimation and 3D shape completion.
- Proposal of **dual depth for efficient and accurate 3D modeling**.
- Proposal of **multi-depth estimation generalization**.
- Validation using a **large-scale medical dataset** (2651 images).

Method



Conventional single-depth-map loss

$$\mathcal{L}_{si} = \alpha\sqrt{\frac{1}{|I|}\sum_{i\in I} g_i^2 - \frac{\lambda_{var}}{|I|^2}(\sum_{i\in I} g_i)^2}, g_i = \log\hat{y}_i - \log y_i$$

Proposed multi-depth-map loss: object-dependent

$$\mathcal{L}_{si}^{dep} = \alpha\sqrt{\frac{1}{\sum_{j\in J}|I^j|}\sum_{j\in J}\sum_{i\in I^j}(g_i^j)^2 - \frac{\lambda_{var}}{(\sum_{j\in J}|I^j|)^2}(\sum_{j\in J}\sum_{i\in I^j} g_i^j)^2}$$

Proposed multi-depth-map loss: object-independent

$$\mathcal{L}_{si}^{indep} = \frac{\alpha}{|J|}\sum_{j\in J}\sqrt{\frac{1}{|I^j|}\sum_{i\in I^j}(g_i^j)^2 - \frac{\lambda_{var}}{|I^j|^2}(\sum_{i\in I^j} g_i^j)^2}$$

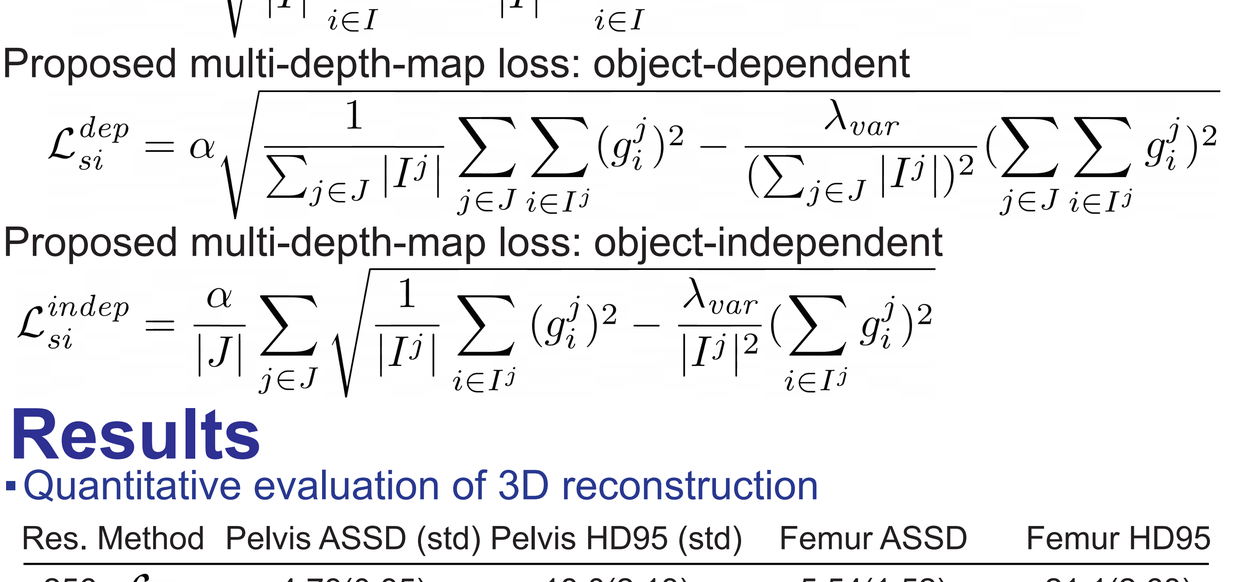
Results

▪ Quantitative evaluation of 3D reconstruction

Res.	Method	Pelvis ASSD (std)	Pelvis HD95 (std)	Femur ASSD	Femur HD95
256	$\mathcal{L}_{si}$	4.78(0.85)	18.0(2.13)	5.54(1.52)	21.1(2.63)
256	$\mathcal{L}_{si}^{dep}$	1.96(0.77)	5.38(2.09)	2.20(1.66)	5.60(4.39)
256	$\mathcal{L}_{si}^{indep}$	1.95(0.78)	5.36(2.10)	2.15(1.66)	5.49(4.38)
1024	$\mathcal{L}_{si}^{indep}$	**1.76**(0.75)	**4.82**(2.02)	**1.95**(1.55)	**5.07**(4.19)

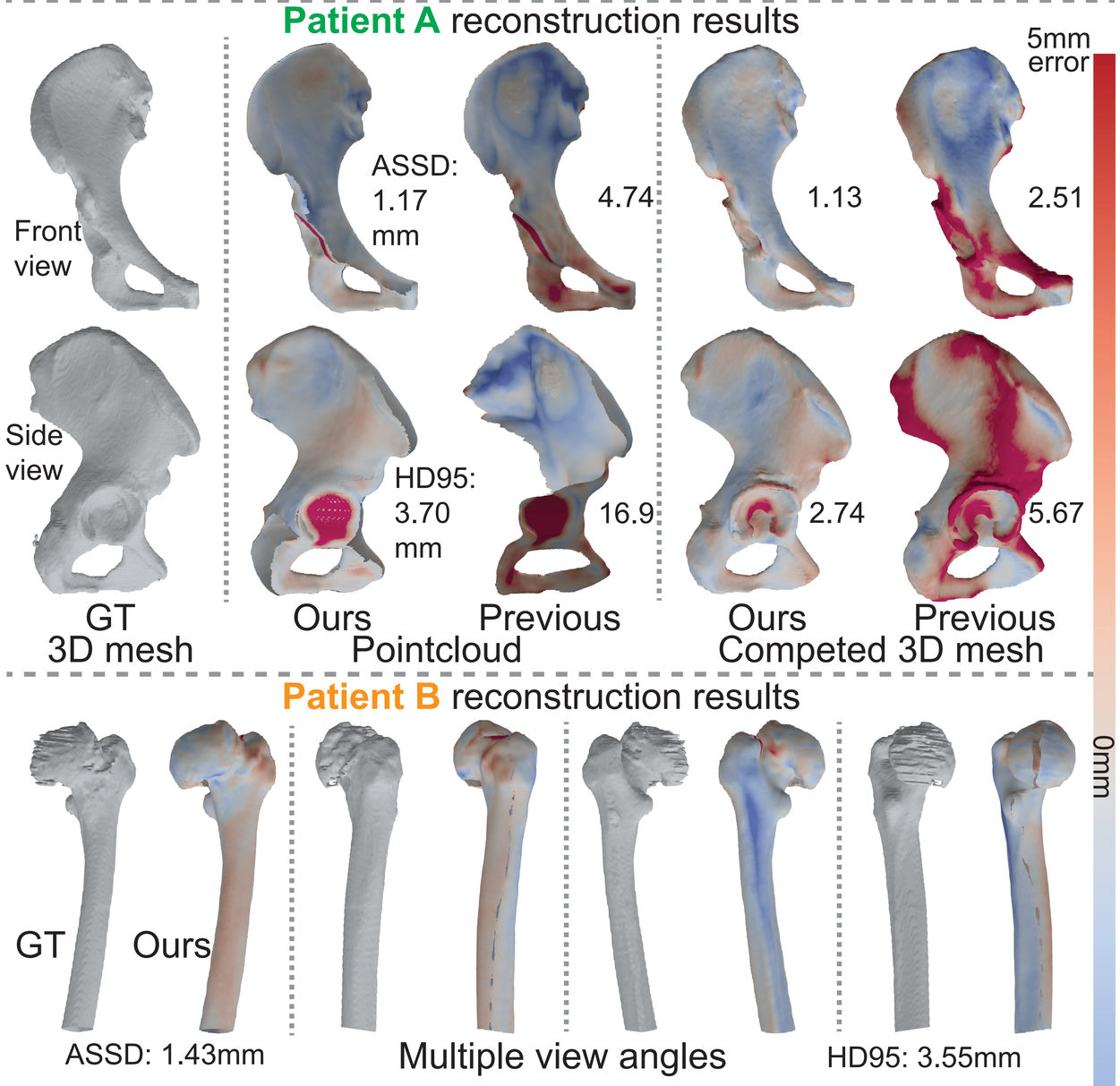
error in mm

▪ Predicted (masked) dual-face depth maps



▪ Predicted 3d shape

X-ray images with predicted boney labels



Conclusion

- We proposed a 3D reconstruction method, 3DDX, for **3D bone modeling from a single radiograph**.
- We proposed dual-depth estimation from an X-ray for **efficient and accurate 3D bone reconstruction**.
- Our method **significantly improved** the conventional single-depth estimation methods by a large margin on a large-scale medical dataset, showing **high potential in clinical applications**.
- We will apply our method on **other bones and modalities**.

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