

Tomographic Reconstruction of Bone from Multi-View X-ray Images Using Planar Markers

平面マーカーを用いた
骨の多視点X線画像からの断層再構成

Empowerment Informatics Program 1st Year

Computer Vision and Image Media Lab

PRAGYAN SHRESTHA

Supervising Professor

ITARU KITAHARA



術中画像診断

- ▶ 手術中に撮影を行なって手術状況を把握

WHEN

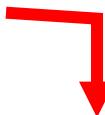
- ▶ 低侵襲手術
- ▶ 整形外科手術

WHY

- ▶ 手術部の内部を確認するため
- ▶ インプラント装着

HOW

{ X-ray
MRI
OCT
...



骨のコントラストが
大きい



L. Jeyaseelan et. al., "Intra-Operative 3-Dimensional Imaging (O-arm) in Foot and Ankle Trauma Surgery: Report of 2 Cases and Review of the Literature"



術中X線透視撮影の問題点

▶ 奥行き情報の消失

WHY X線の持つ透過的な性質

Beer Lambert's Law

$$I = I_0 \exp\left(- \int_L f(r) dr\right)$$

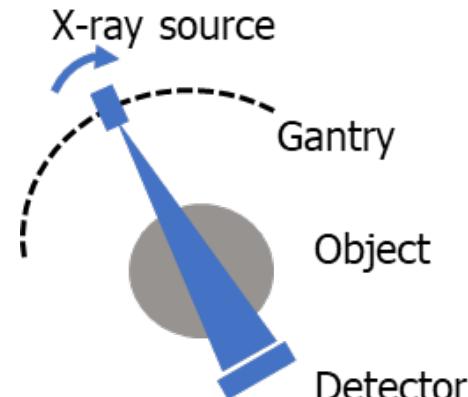
I is the intensity, $f(r)$ is the attenuation constant

▶ Computed Tomography



GE LightSpeed CT scanner [1]

術中には使えない



撮影姿勢の正確情報が必要



提案手法

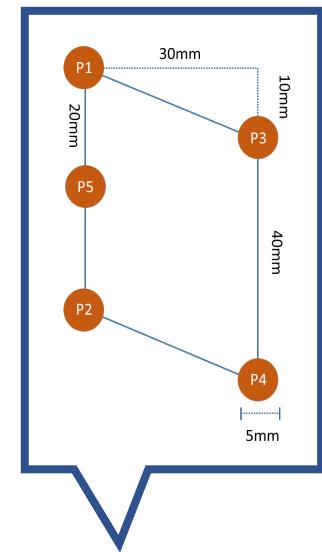
▶ 平面マーカを用いたキャリブレーション およびX線画像からの断層再構成

- HOW

- ▶ キャリブレーション平面上の**5点**にマーカを配置
- ▶ 被写体を回転

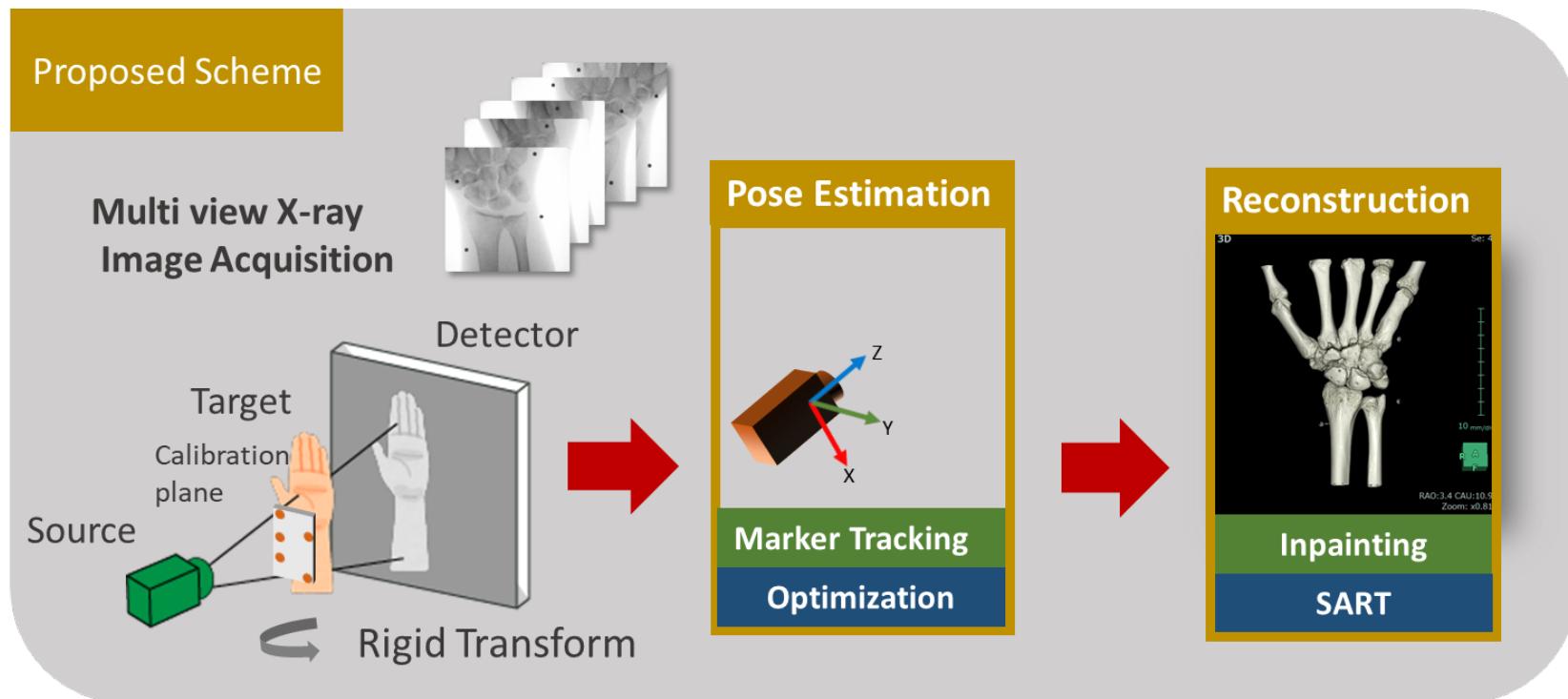
- WHY

- ▶ 平面マーカの作成が容易
- ▶ 姿勢を算出するため外部センサー不要
- ▶ 定期的なキャリブレーション不要





Overview of Proposed Method



2段階

→

ポーズ推定 → 再構成



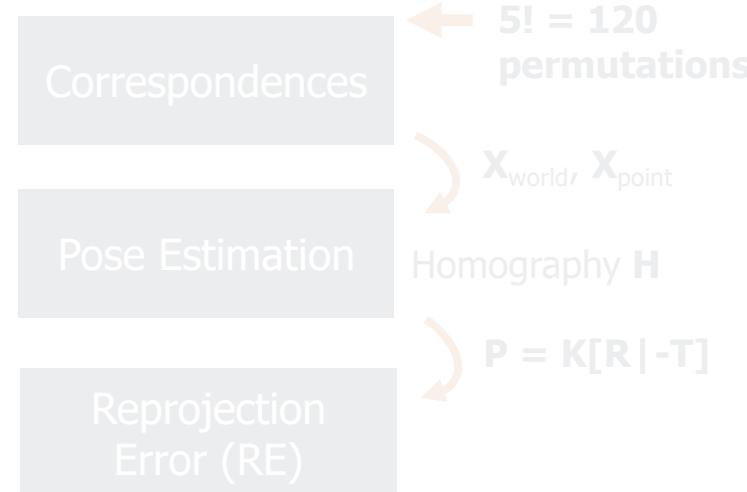
Pose Estimation

Marker Tracking



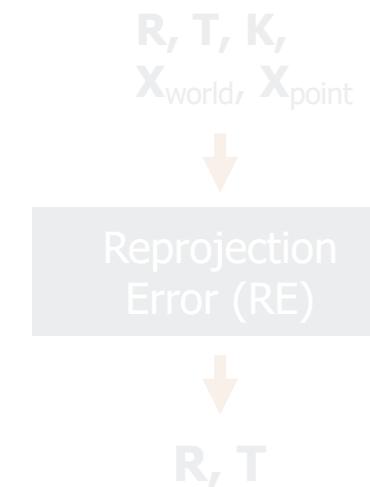
1. Simple Thresholding
2. Connected Components
3. Compute **Centroid**

Correspondence Matching



Choose the **Pose** and **Correspondence** with the minimum RE

Optimize



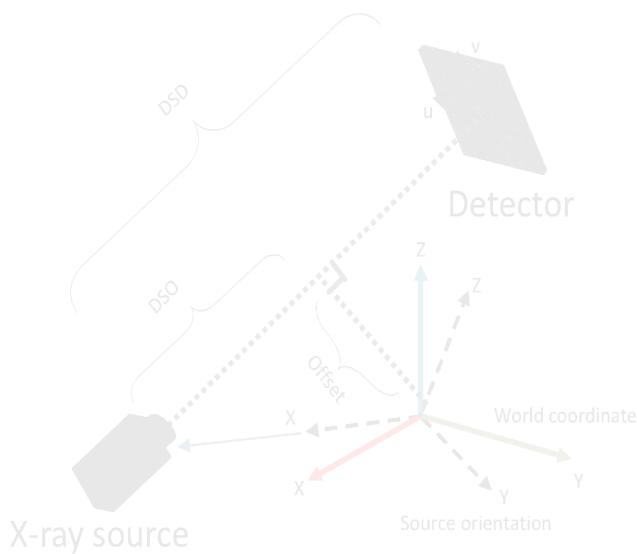
$$\text{RE} = \sum_{i=1}^5 \|\mathbf{m}_{p'i} - \mathbf{P}\mathbf{x}_{pi}\|$$

\mathbf{m}_{pi} is the image point,
 \mathbf{x}_{pi} is the world point



Tomographic Reconstruction

Geometry Transform



Rotation, Translation

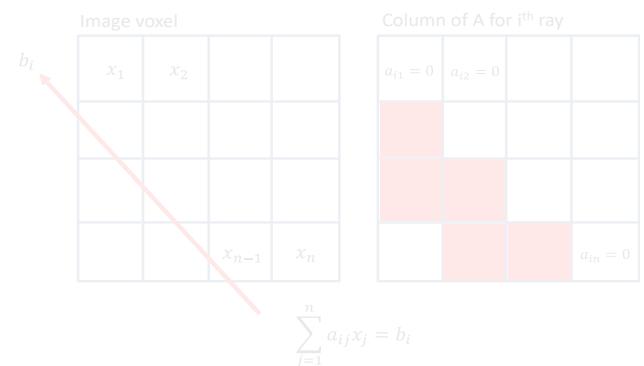


Detector to Source,
Source to Object, Offset ...

Inpainting



Algebraic Reconstruction Technique



$$\hat{\mathbf{x}} = \operatorname{argmin} \|\mathbf{b} - \mathbf{Ax}\|$$

\mathbf{x} is image vector, \mathbf{b} is projection vector
 \mathbf{A} is the system geometry matrix

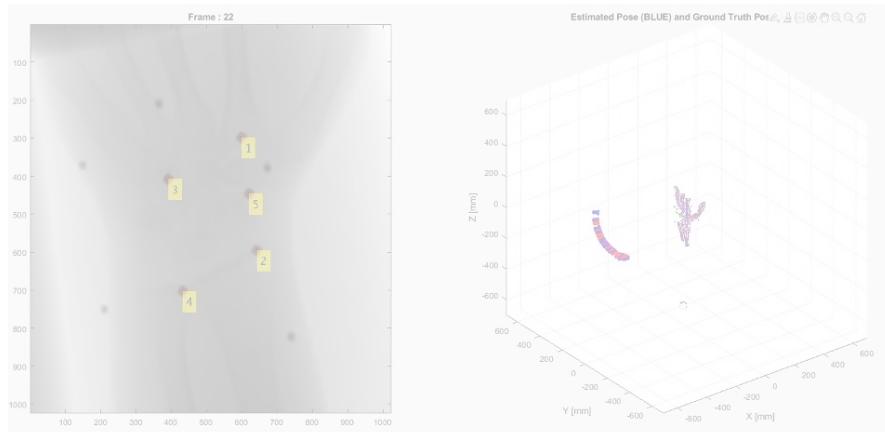
jth component of \mathbf{x} in kth iteration

$$x_j^{(k+1)} = x_j^{(k)} + \frac{b_i - \sum_{l=1}^n x_l^{(k)} a_{il}}{\sum_{l=1}^n a_{il}^2} a_{ij}$$

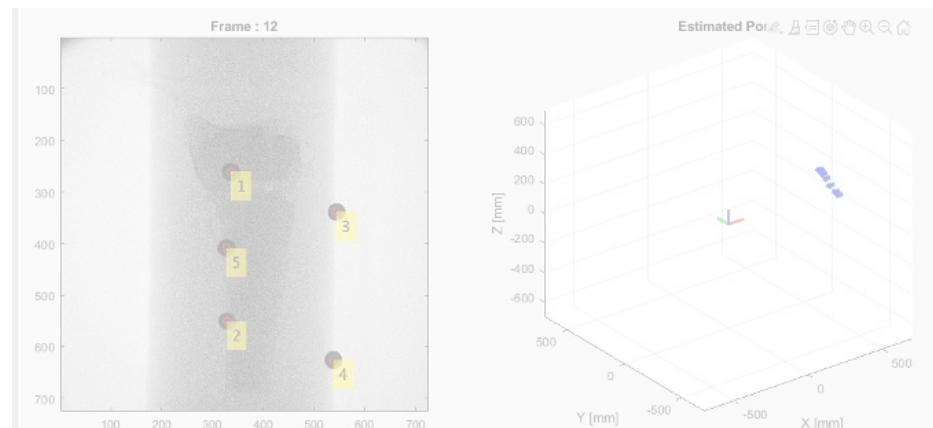


Experimental Setup

Simulation



Real Data



► To test pose estimation

Simulated target rotation using
HTC VIVE PRO Controller



Simulated X-ray projection using
TIGRE^[2] (MATLAB)

► To test reconstructed image quality

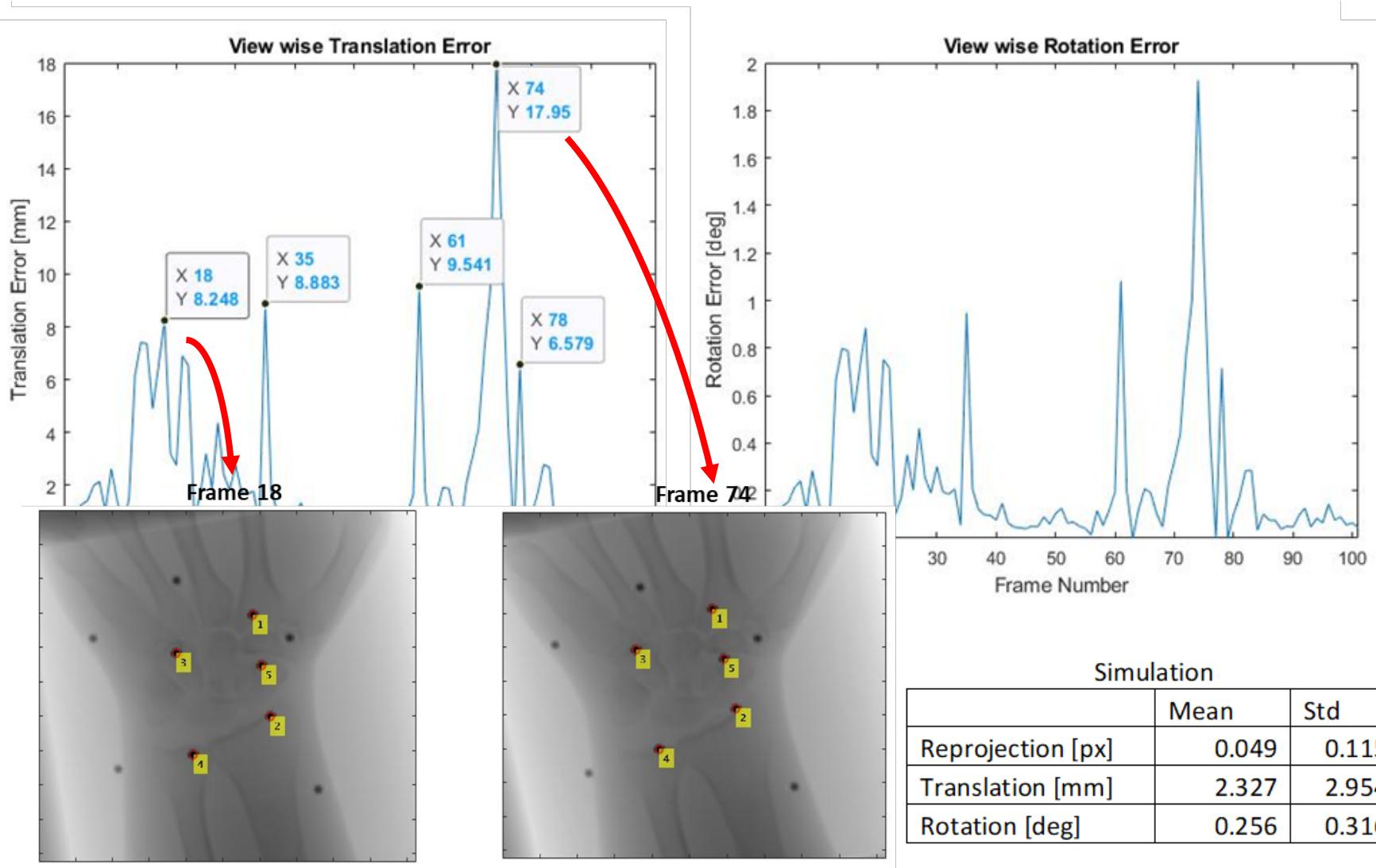


Fractured bone
phantom





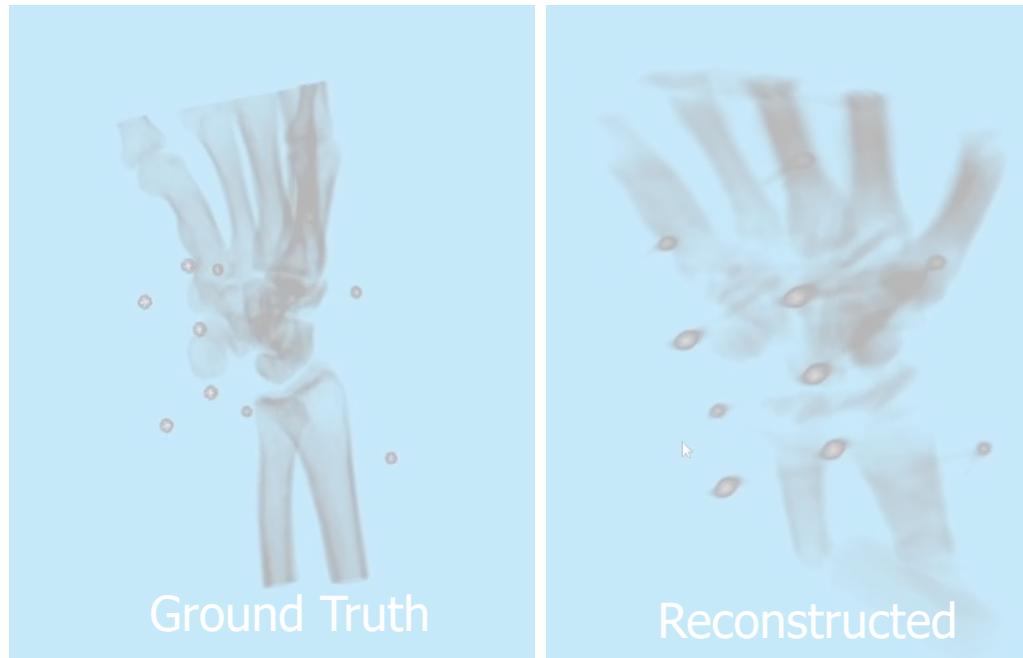
Result of Pose Estimation





Result of Image Reconstruction from Simulated Projection

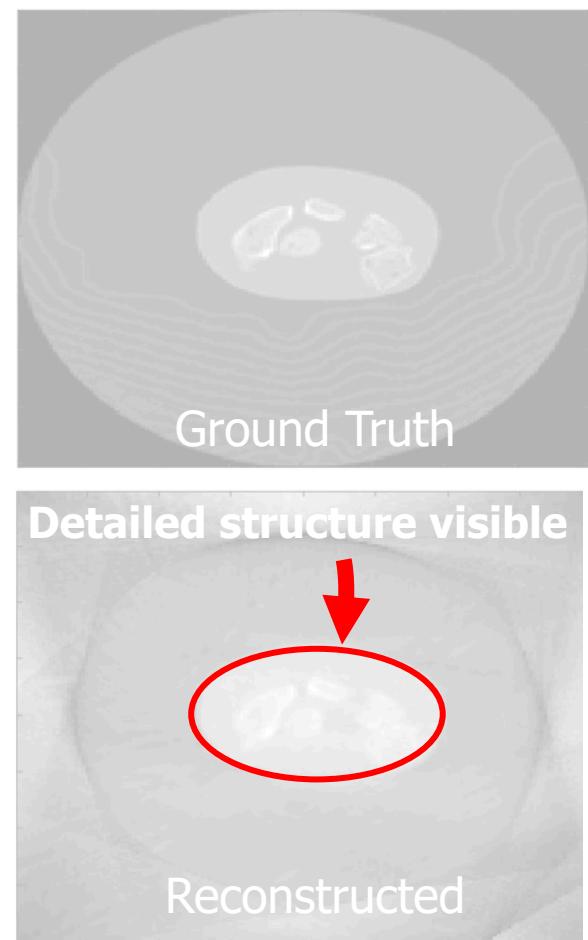
Volume Rendering



Ground Truth

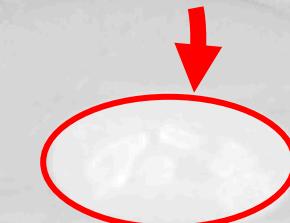
Reconstructed

Axial Slice



Ground Truth

Detailed structure visible



Reconstructed

Voxel size: $161\text{px} \times 161\text{px} \times 161\text{px}$

Resolution: 1px/mm

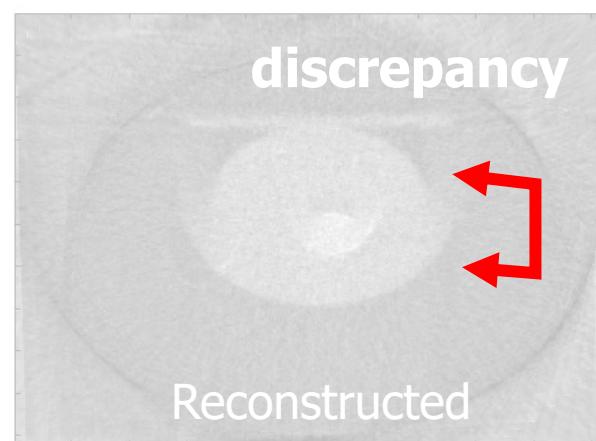
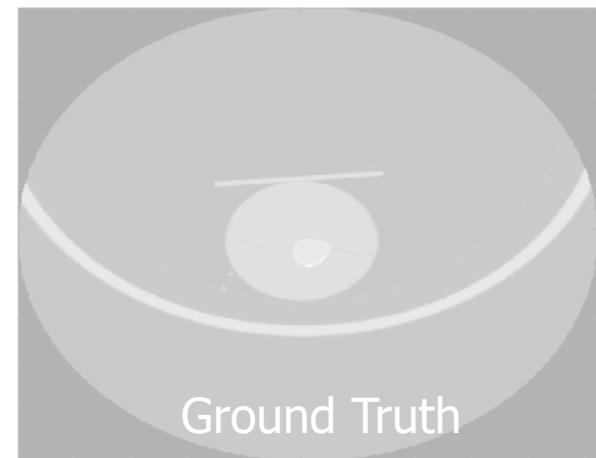


Result of Image Reconstruction from Real Data

Volume Rendering



Axial Slice



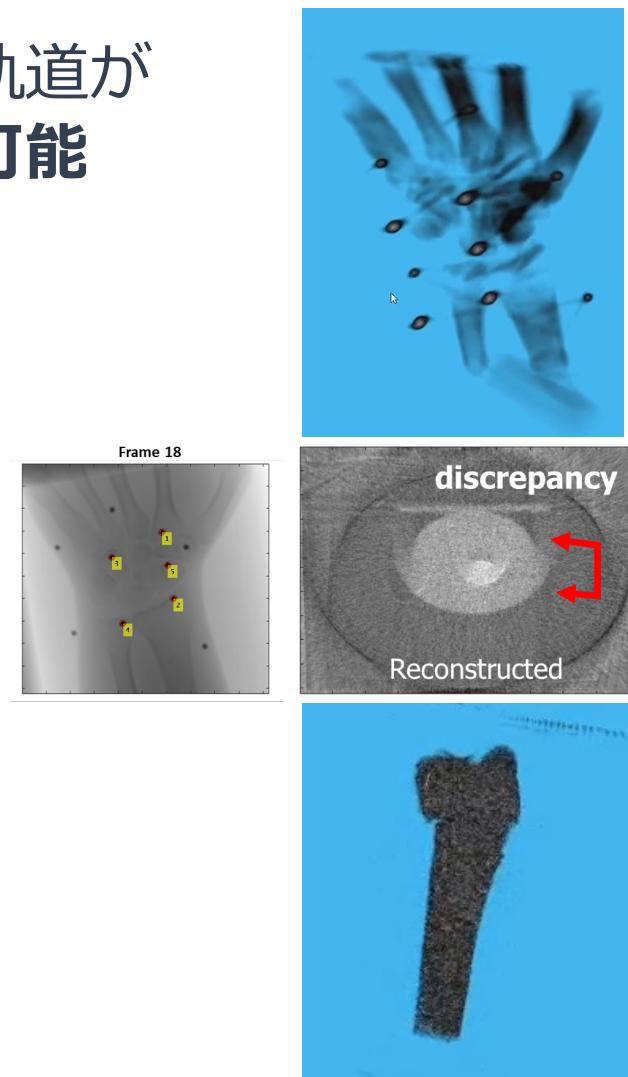
Voxel size: 512px×512px×512px

Resolution: 4px/mm



Conclusion

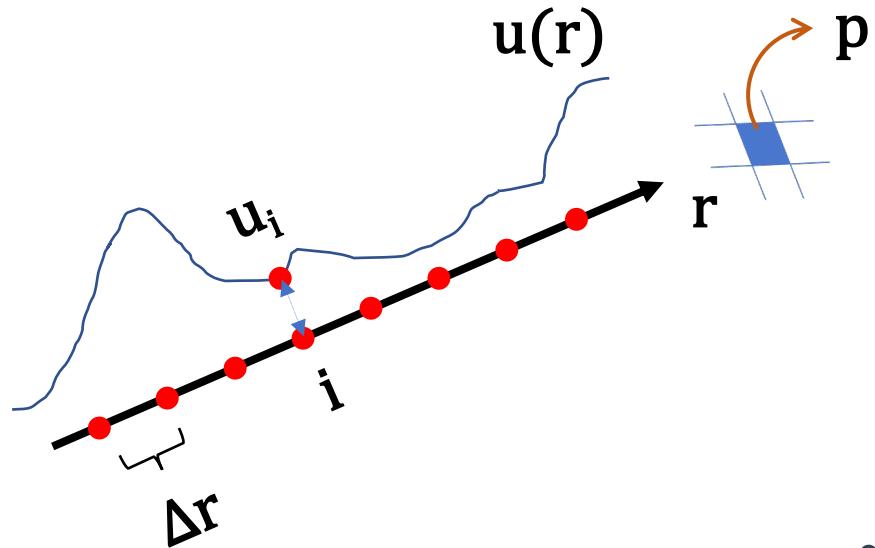
- ▶ シミュレーションの結果より、撮影軌道が完全円軌道でない場合も形状復元は可能
- ▶ 平面マーカーを用いたキャリブレーションでは正面から撮った画像の精度が落ちる
- ▶ 再構成画像の画質を上げるためにには正面画像のポーズの最適化が必要





Current Approach

CT問題の再定式化：



順投影

$$p = \sum_i u_i \Delta r$$

逆問題

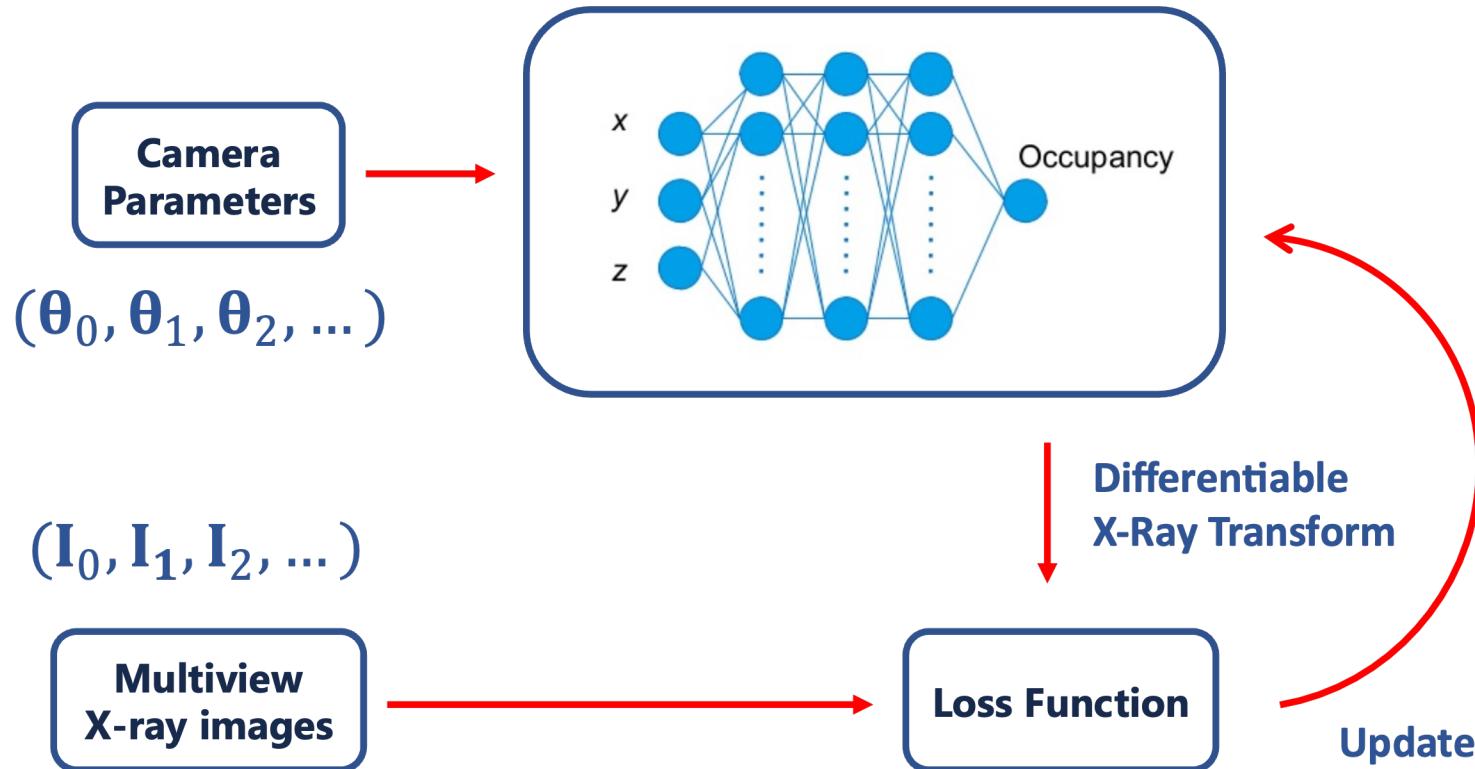
$$p \rightarrow u_i$$

$u(r)$ は減衰率、
 r は位置、
 p は投影画素値

アプローチ
逆投影を行わず、
順投影のみを用いて
 u （減衰率）を学習する



Current Approach



$$|p_i - L| = p_i \left(1 - \sum_j \phi_j \right)$$