Dynamic Geometry Processing

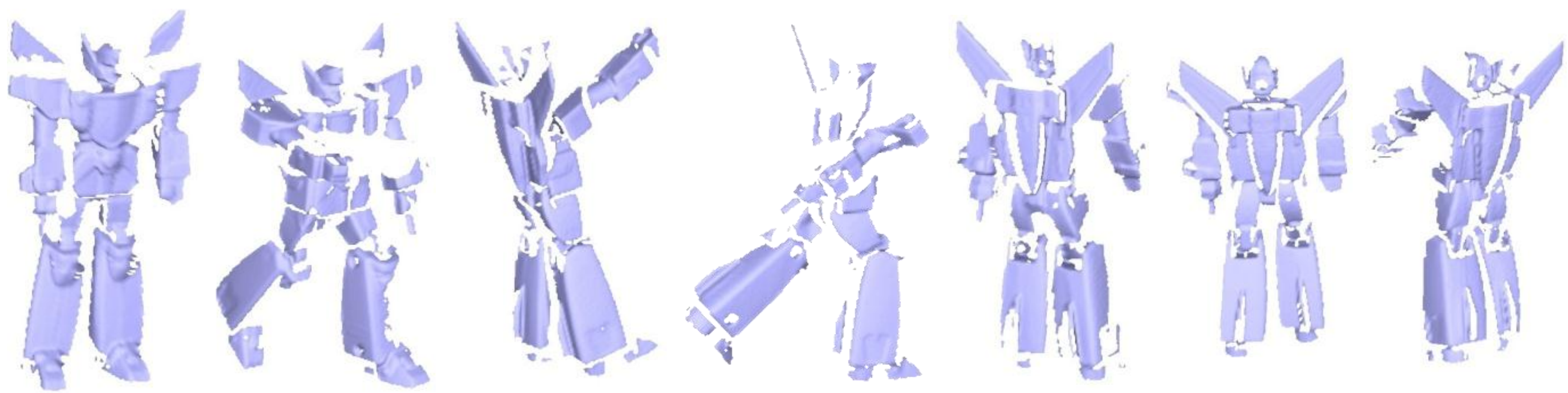
EG 2012 Tutorial

Will Chang, Hao Li, Niloy Mitra,
Mark Pauly, Michael Wand

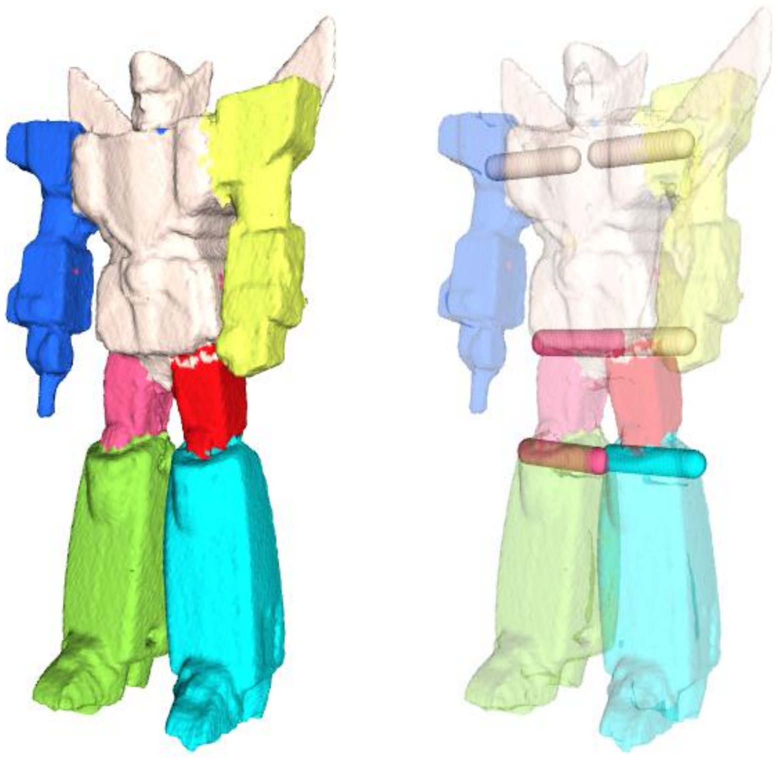
Global Articulated Registration

Global Articulated Registration

- Complete models from dynamic range scans
- No template, markers, skeleton, segmentation
- Articulated models
- Use directly to create new animations



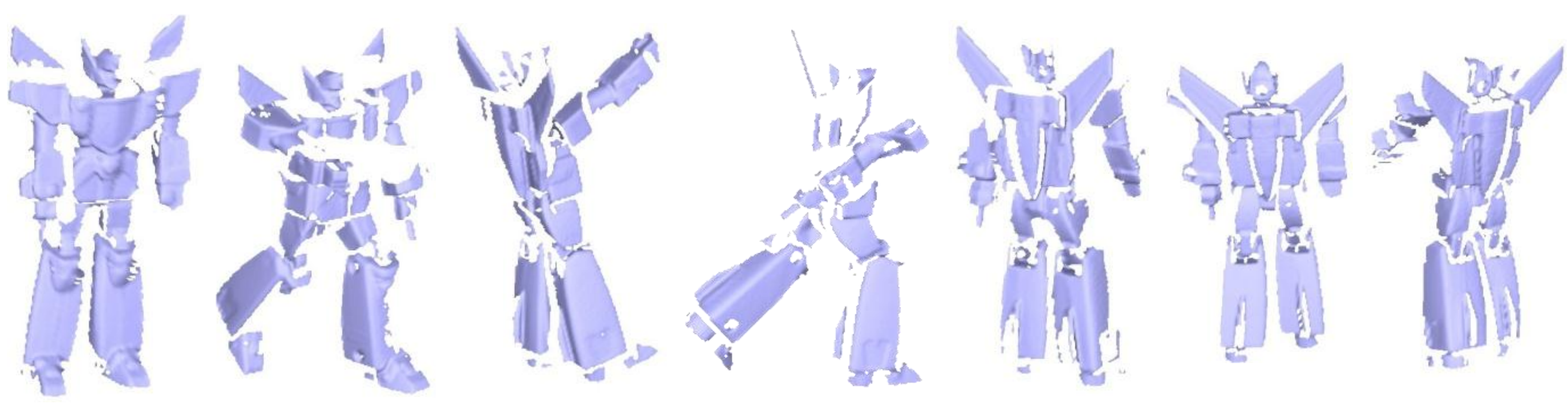
Input Range Scans



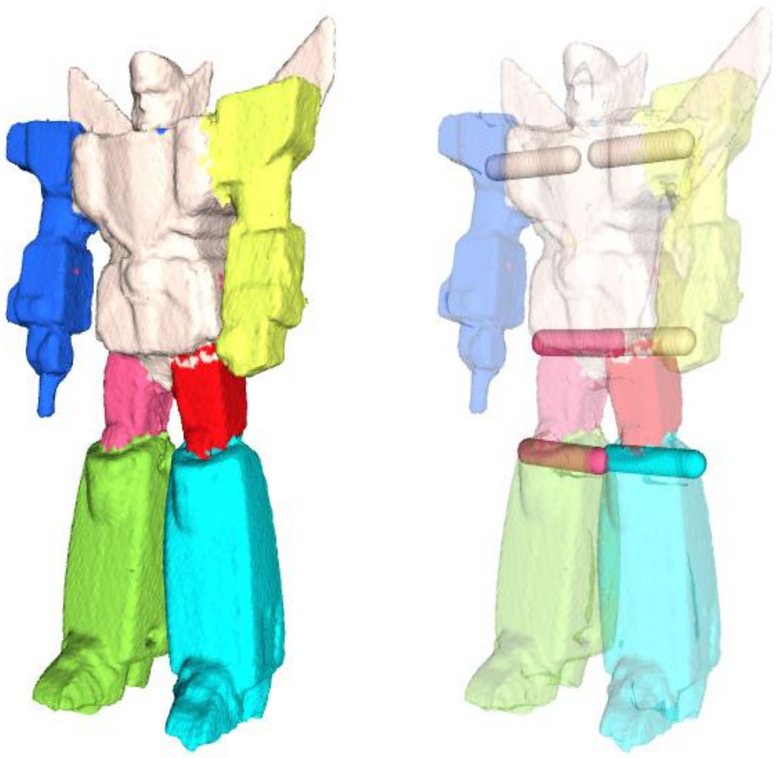
Reconstructed 3D Model

Features

- Handles large, fast motion
- Incomplete scans (holes, missing data)
- Optimization over all scans
- 1 or 2 simultaneous viewpoints



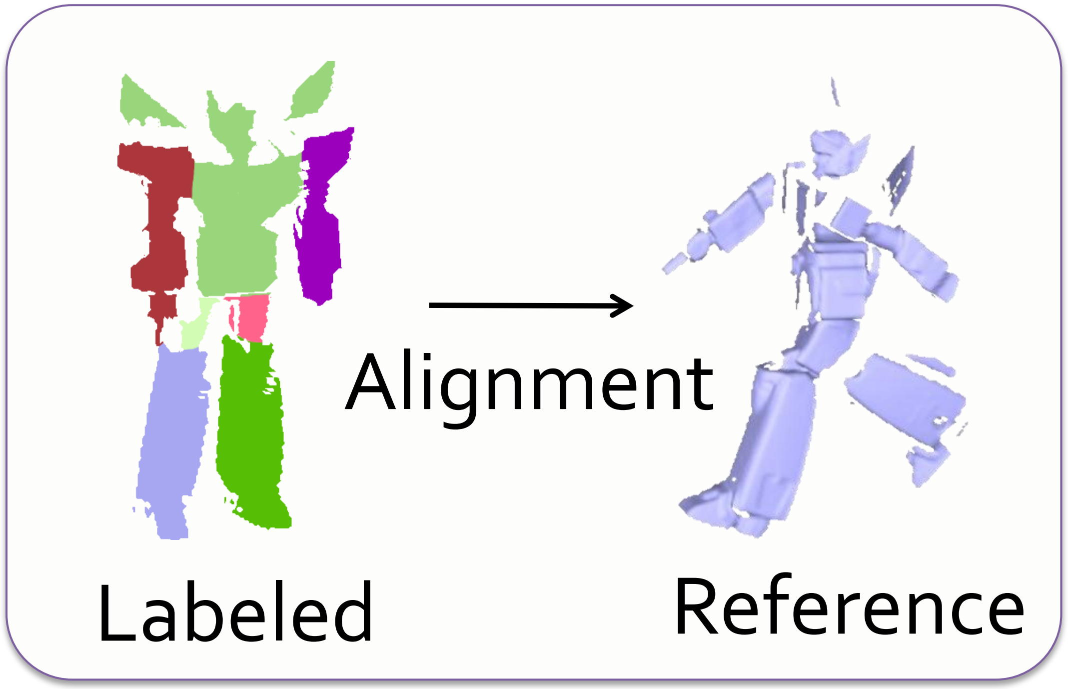
Input Range Scans



Reconstructed 3D Model

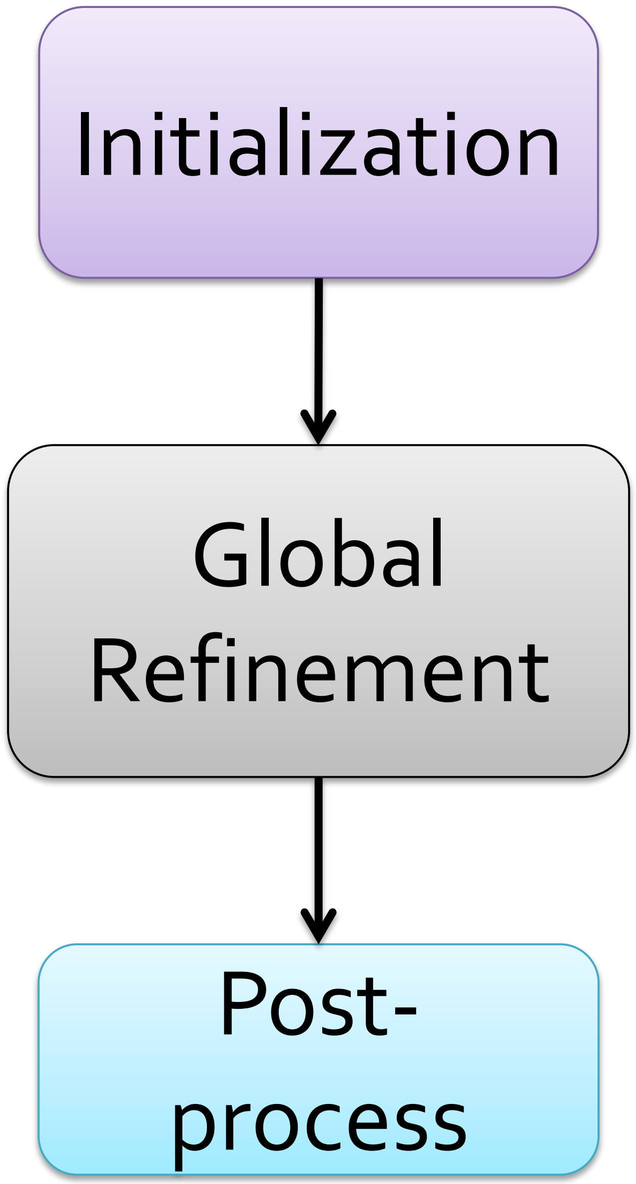
Reconstructing Articulated Models

- **For every frame, determine**
  - **Labeling** into constituent parts (per-vertex)
  - **Motion** of each part into reference pose (per-label)
- Solve simultaneously for labels, motion, joint constraints



Algorithm Overview

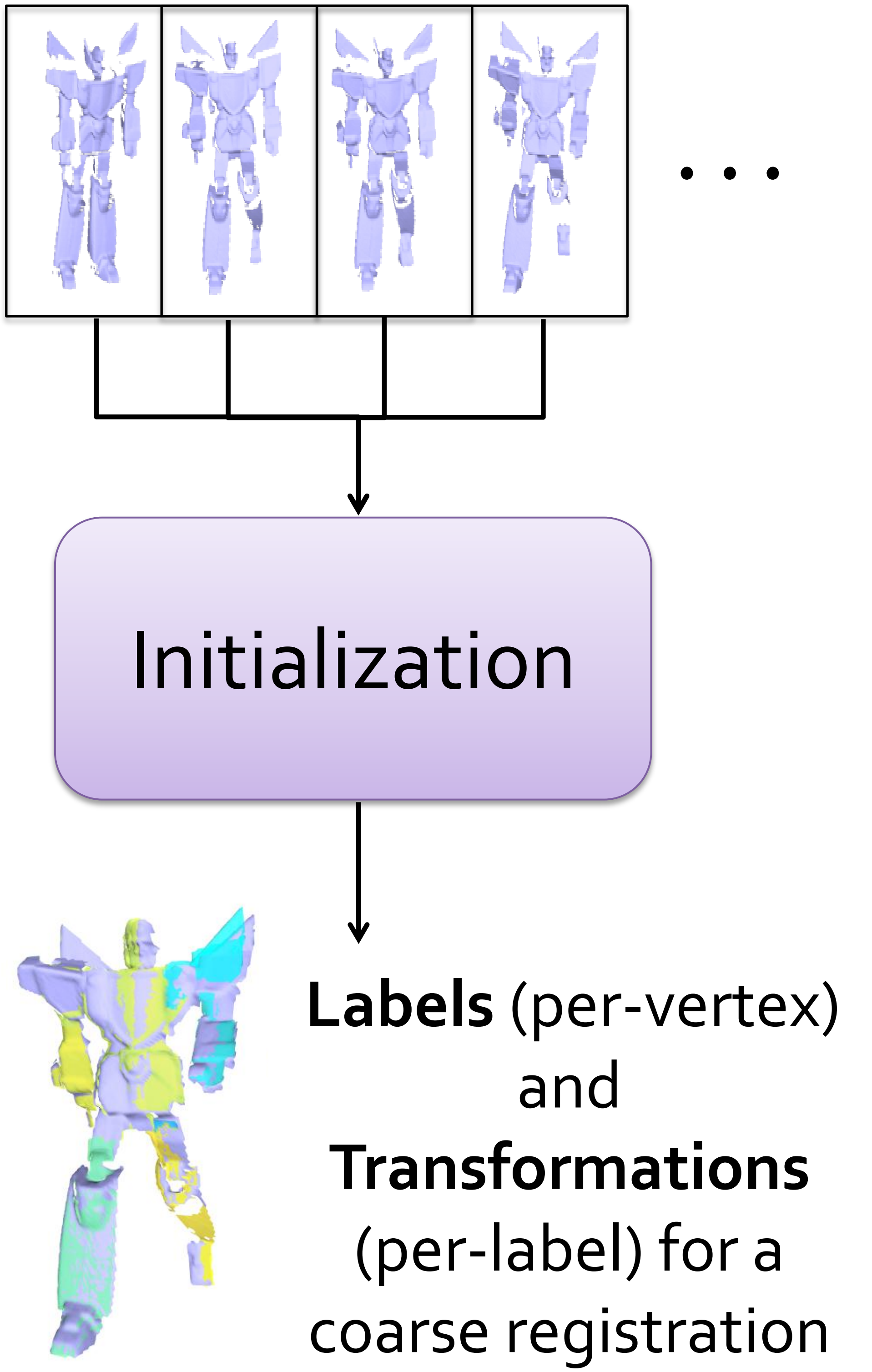
- **Initialization**
- **Global refinement**
- **Post-process**



Algorithm Overview

Initialization

- Coarse pairwise registration



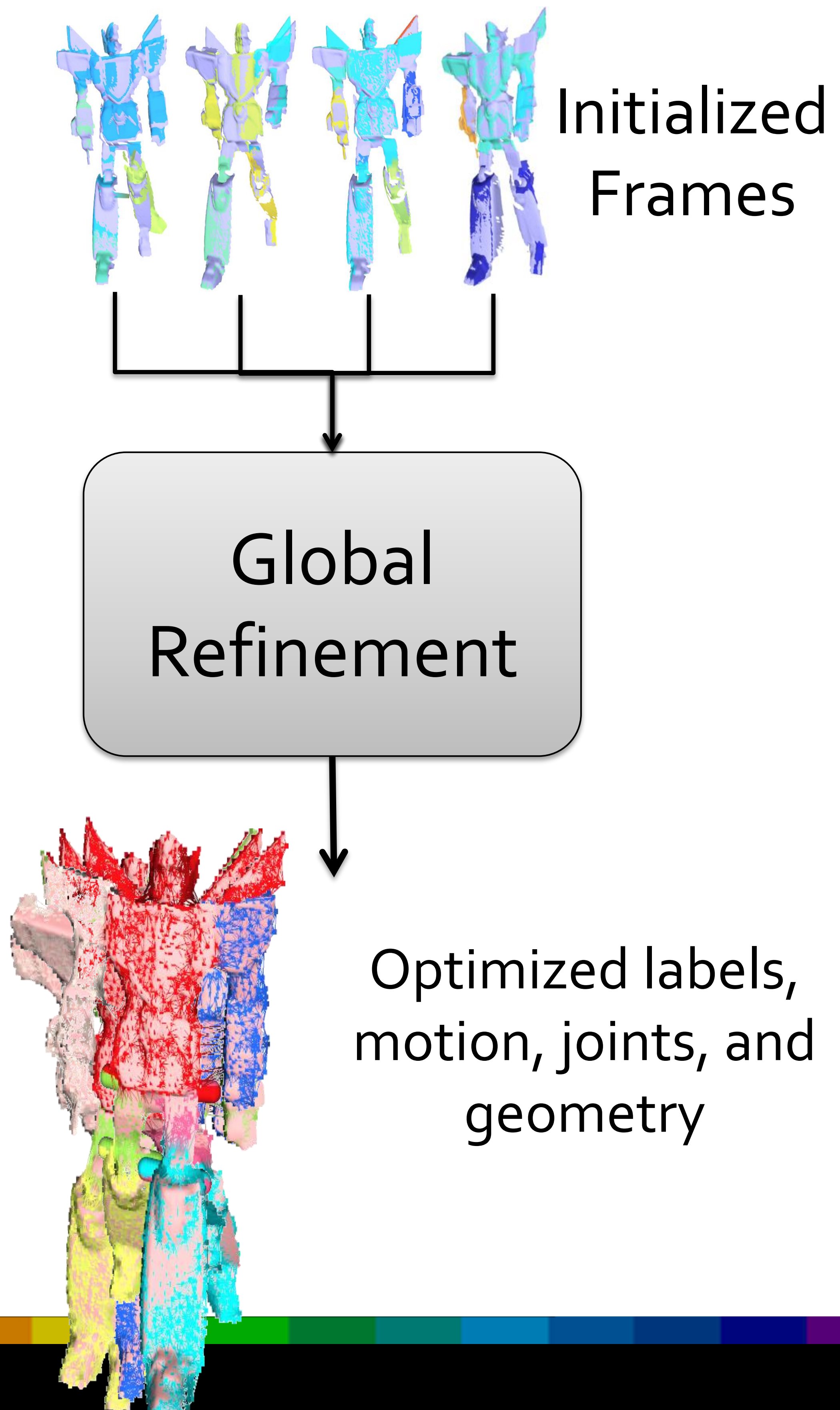
Algorithm Overview

Initialization

– Coarse pairwise registration

Global refinement

– Solve global model incorporating all frames



Algorithm Overview

Initialization

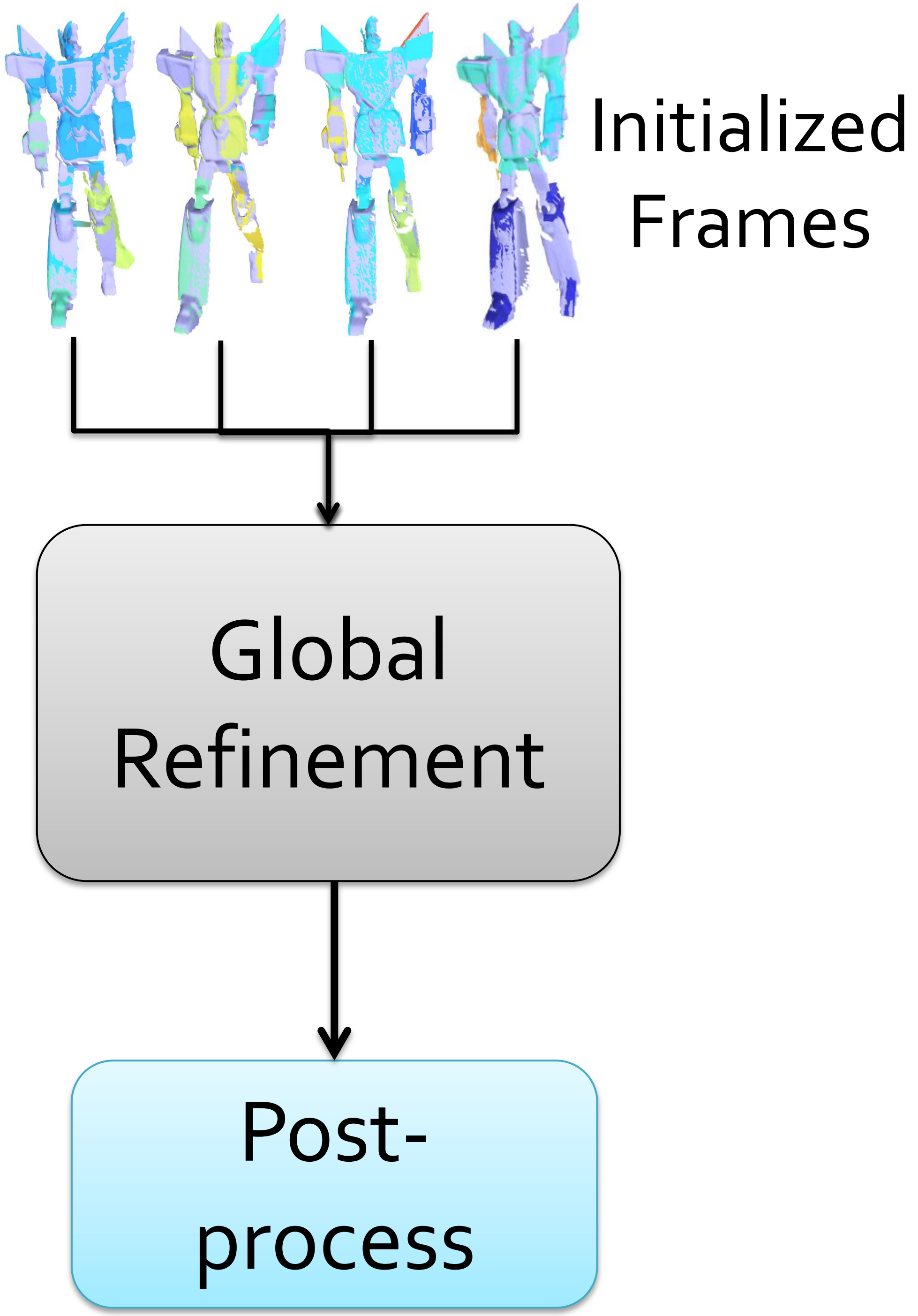
- Coarse pairwise registration

Global refinement

- Solve global model incorporating all frames

Post-process

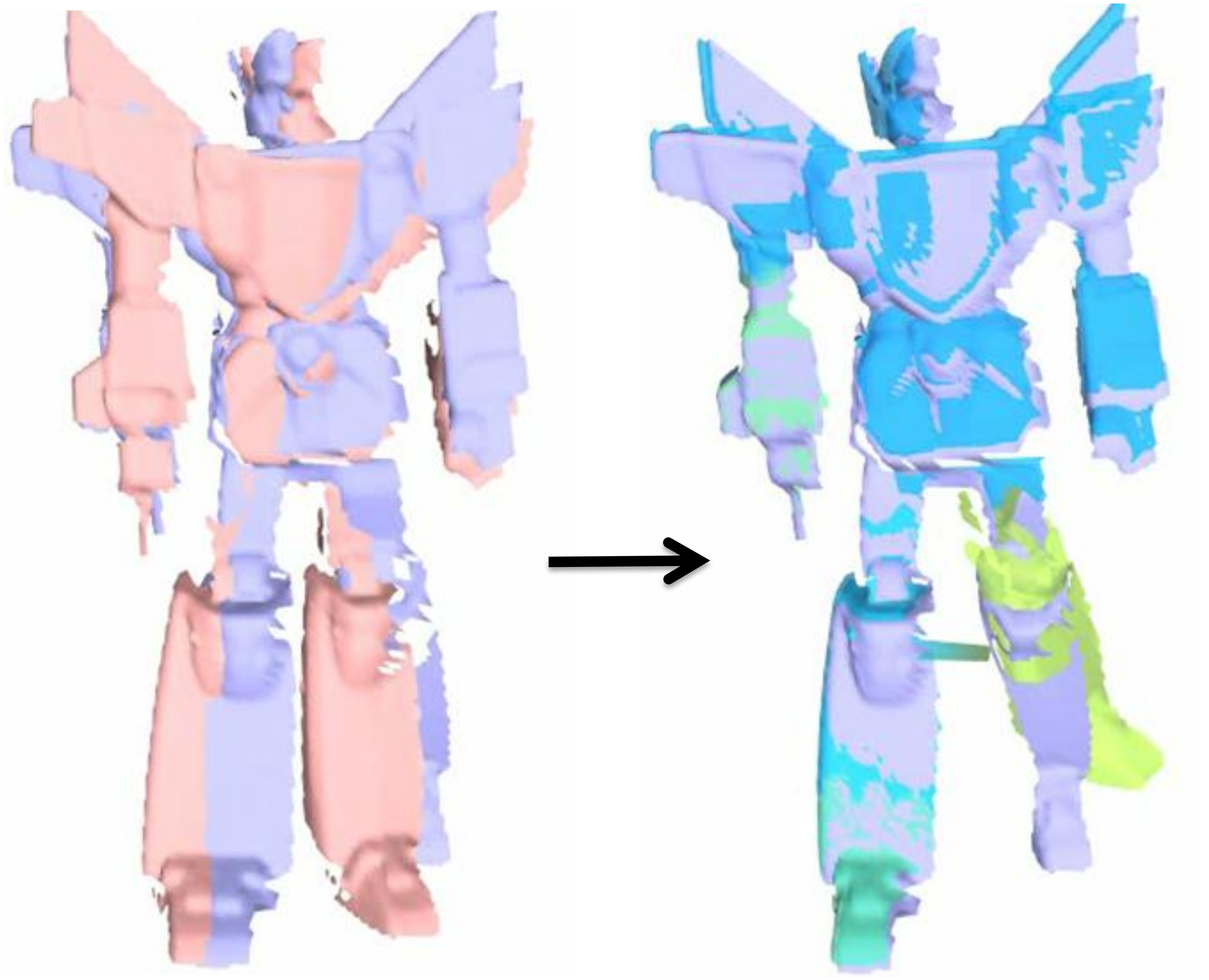
- Gather frames, reconstruct mesh



Part I: Initialization

Initialization

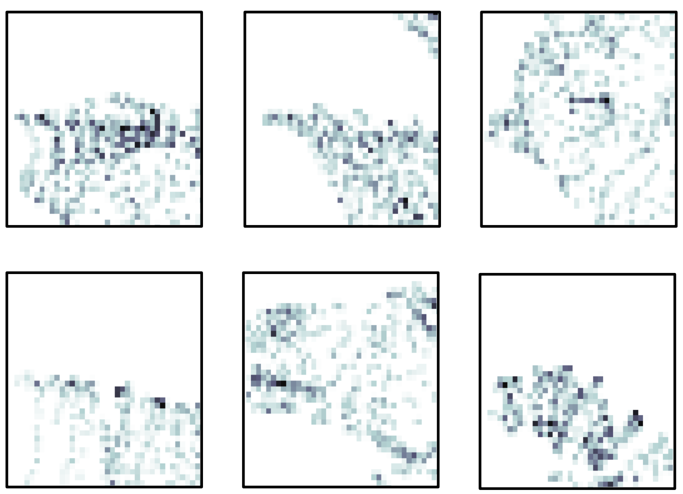
Establish initial correspondence of consecutive frames



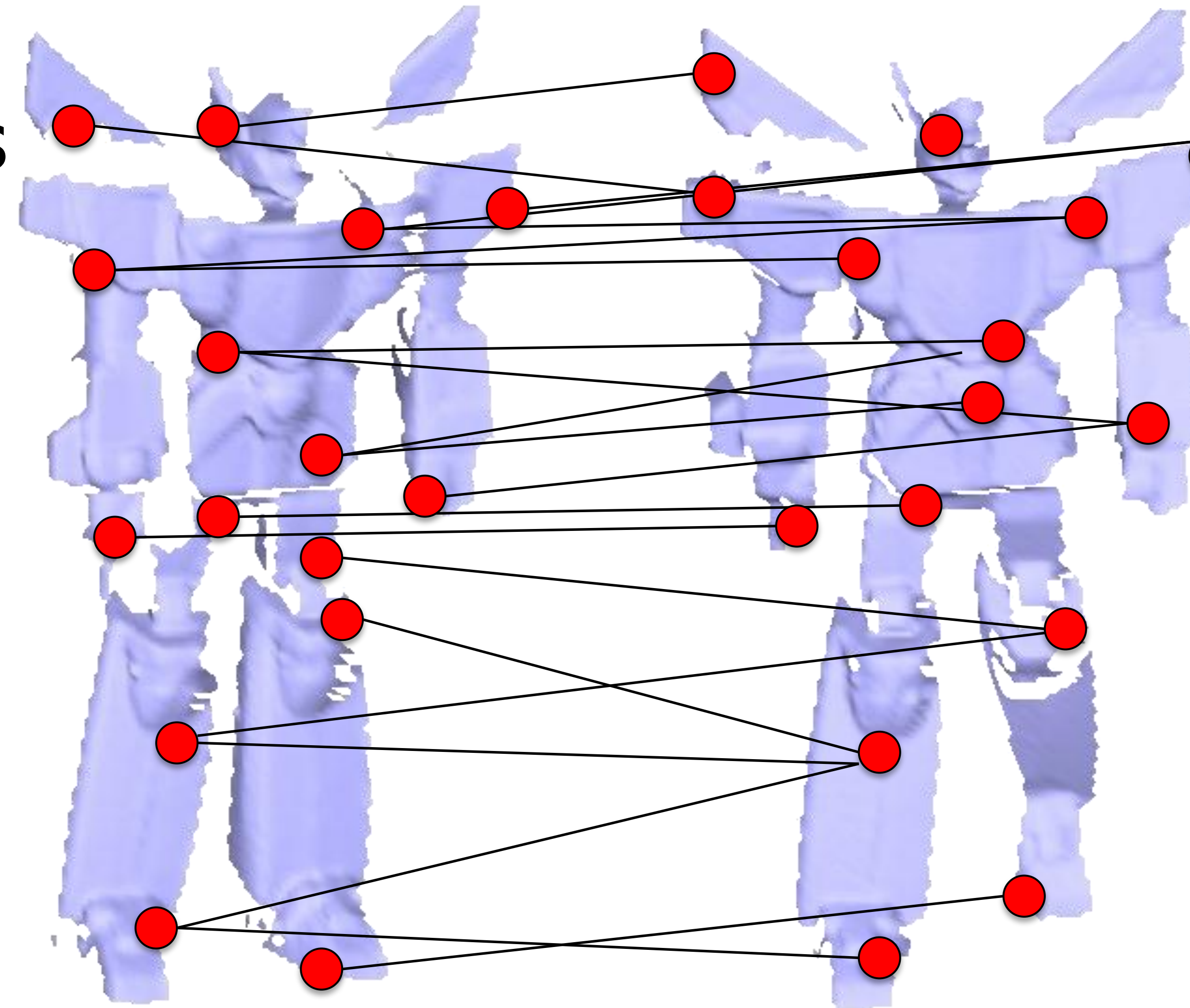
Frame *i* and *i+1* Registered Result

Initialization

1. Point correspondence using feature descriptors



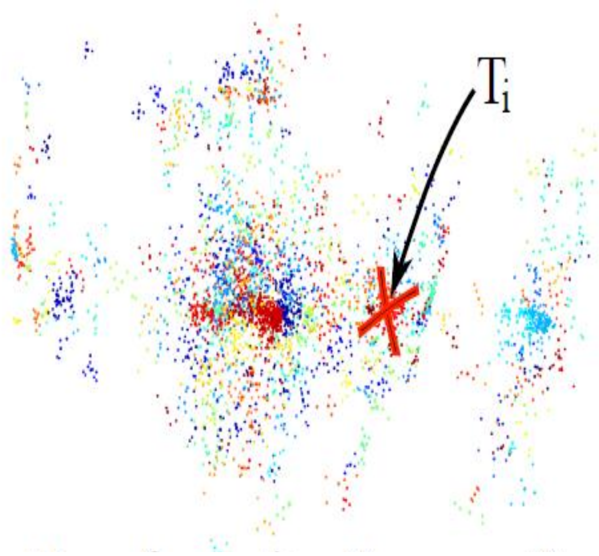
Spin Image examples



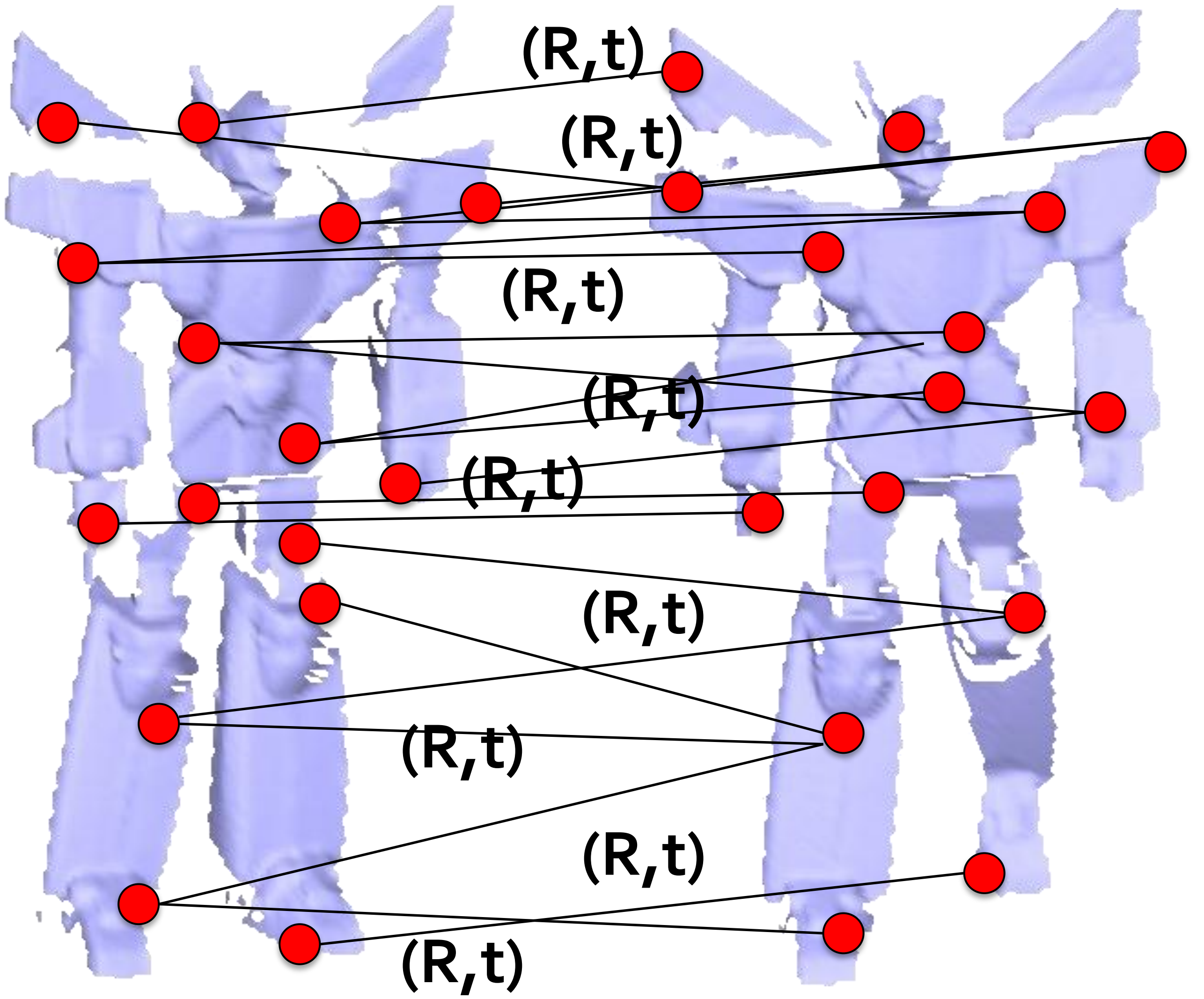
Frame *i* Frame *i+1*

Initialization

1. Point correspondence using feature descriptors
2. Transformation (R,t) per correspondence
3. Cluster (R,t)



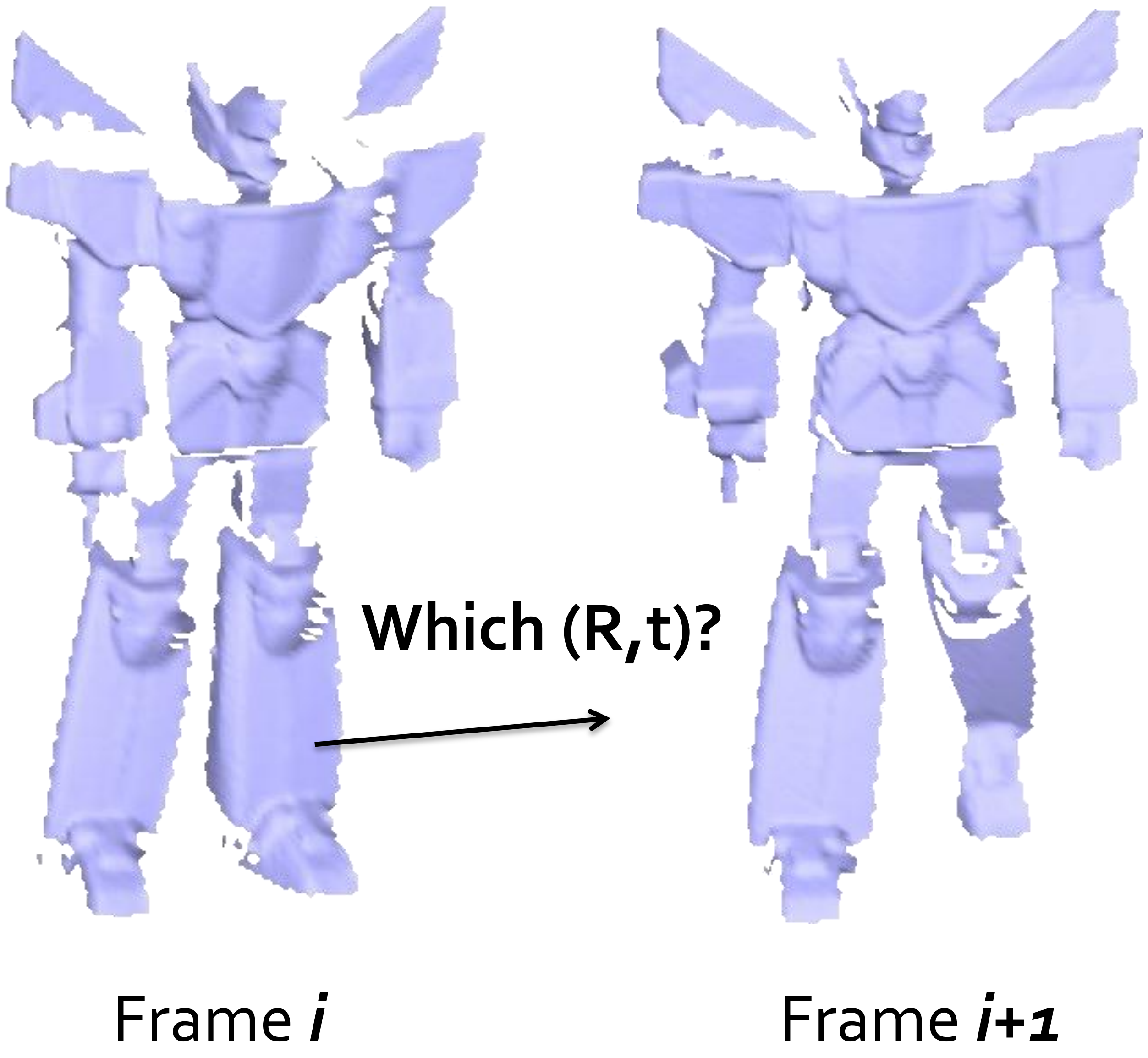
Transformation Space *se(3)*



Frame ***i*** Frame ***i+1***

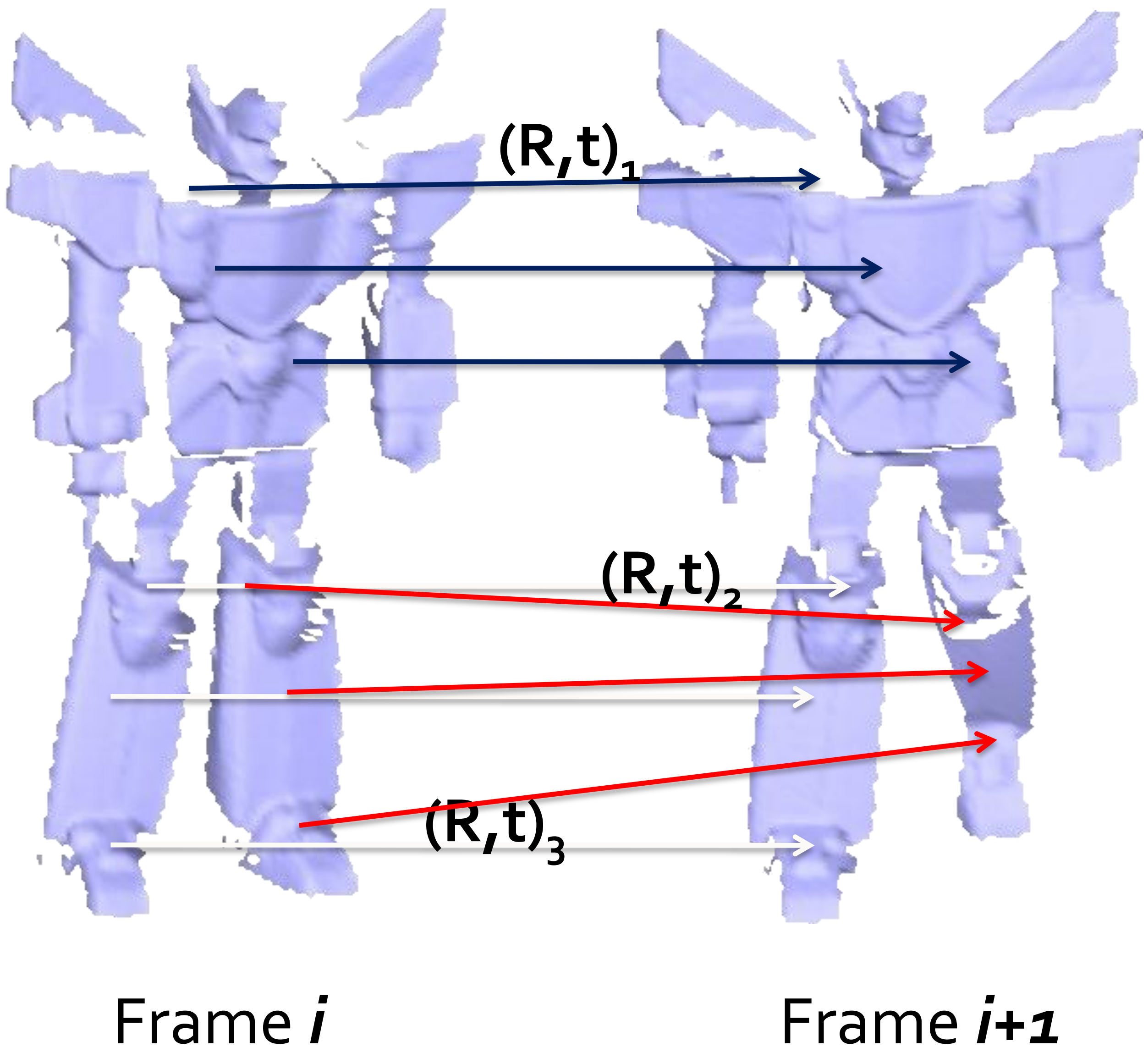
Initialization

1. Point correspondence using feature descriptors
2. Transformation (R,t) per correspondence
3. Cluster (R,t)
4. Optimize using "Graph Cuts" [Boykov et al. 2001]



Initialization

1. Point correspondence using feature descriptors
2. Transformation (R,t) per correspondence
3. Cluster (R,t)
4. Optimize using “Graph Cuts” [Boykov et al. 2001]



Initialization Result

Both Frames

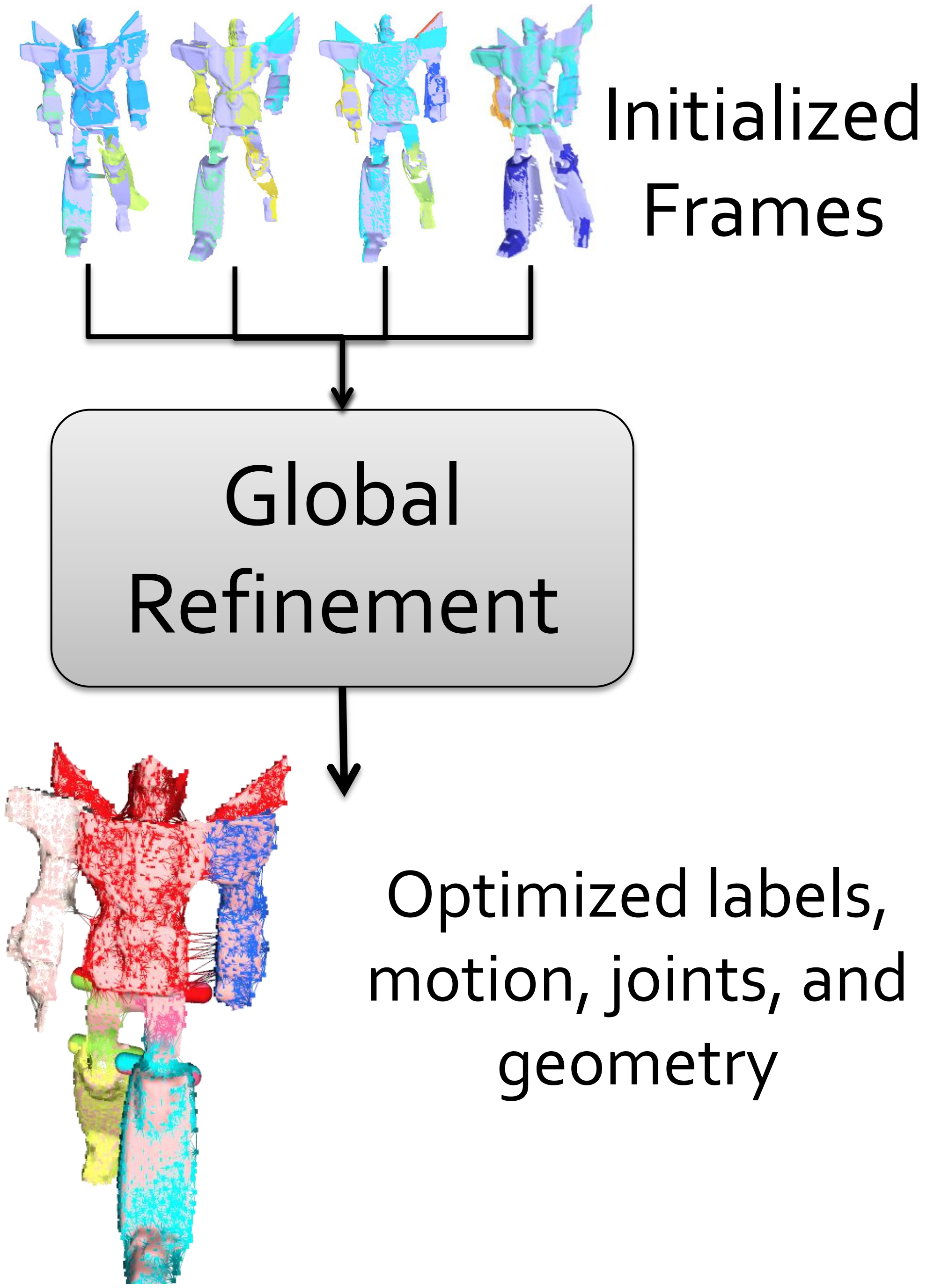
Registered Result

Part II: Global Refinement

Global Refinement

Global refinement

– Solve global model incorporating all frames



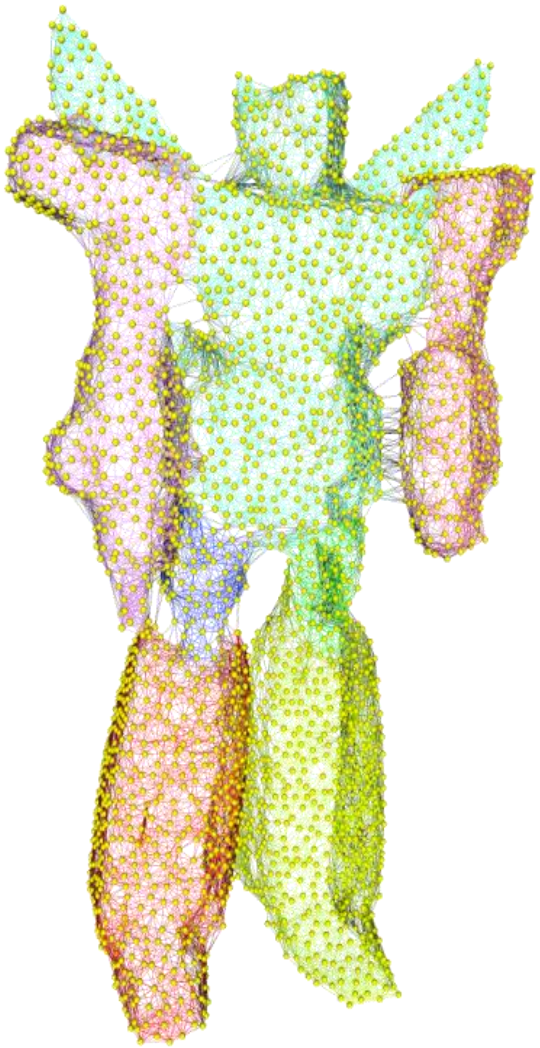
Dynamic Sample Graph (DSG)

Sparse representation

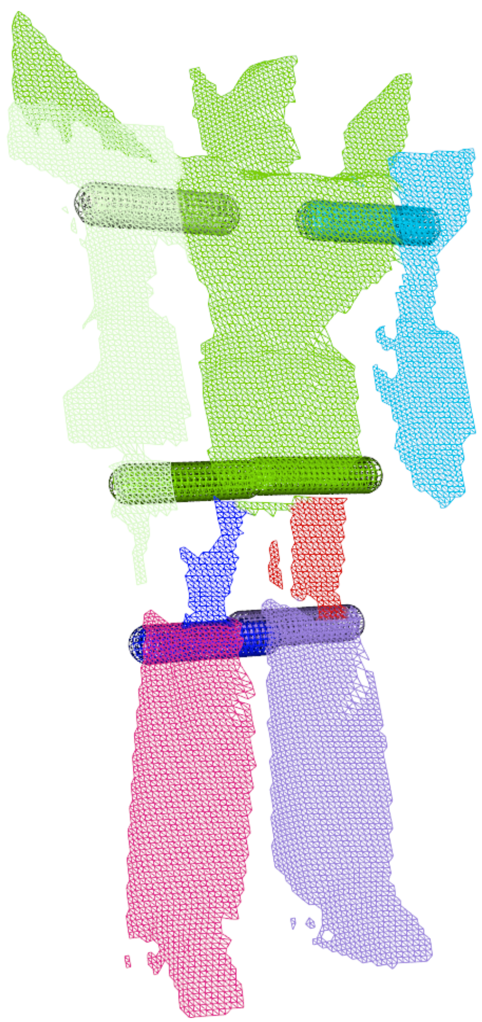
- Increases efficiency
- Joints: part connectivity

Continuously updating

- Update samples from new surface data



Dynamic Sample Graph (DSG)



Extracted Joints

Global Refinement

Fit the DSG to all scans simultaneously (Global Fit)

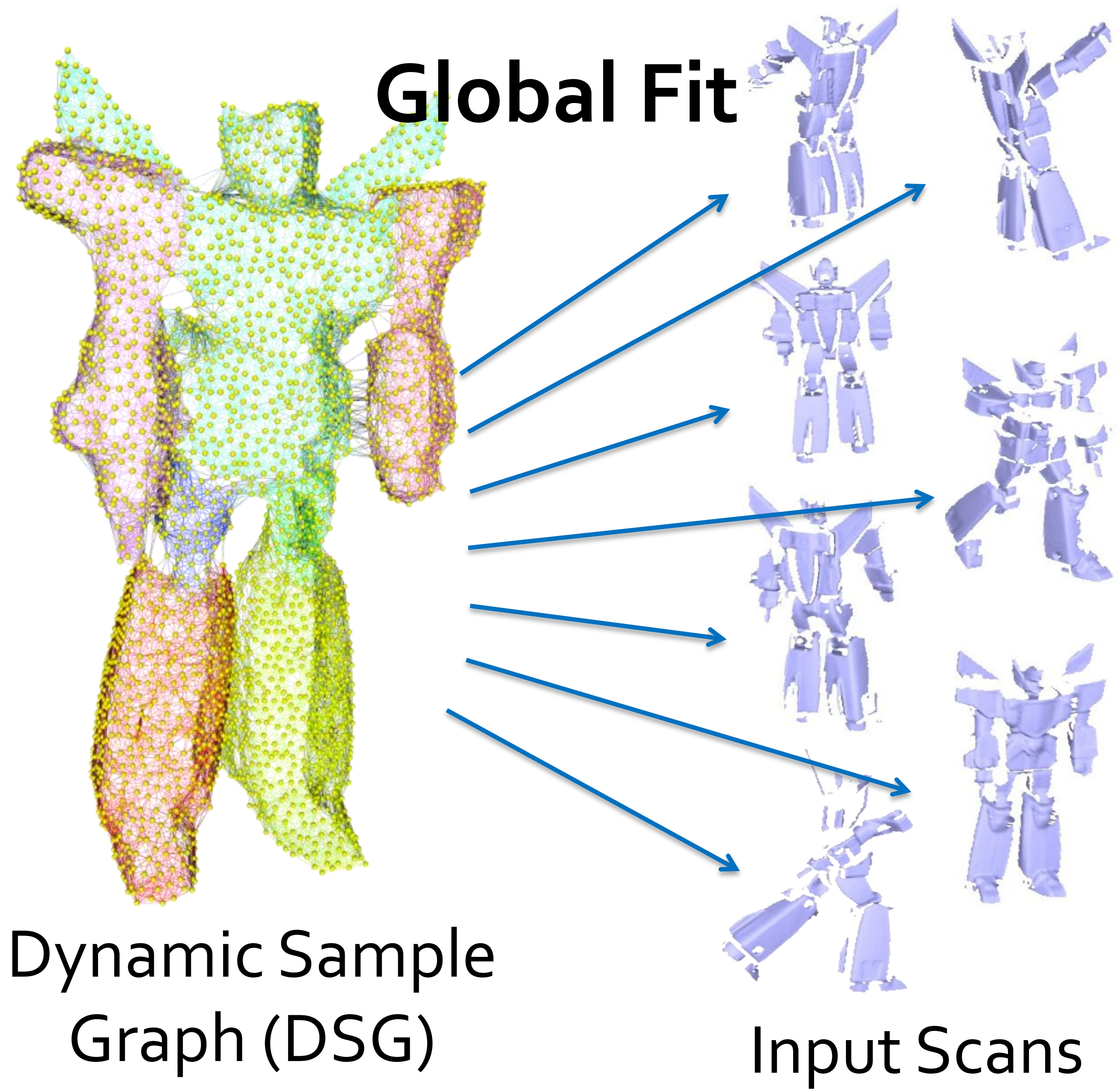
Alternating Optimization

1. Optimize Transformations
2. Optimize Labels
3. Update joint locations

Repeat until convergence

– 3-5 iterations per frame

Update samples



Transformation Optimization

- Align DSG as closely as possible to all scans
- Labels fixed
- Measure alignment using closest point distance

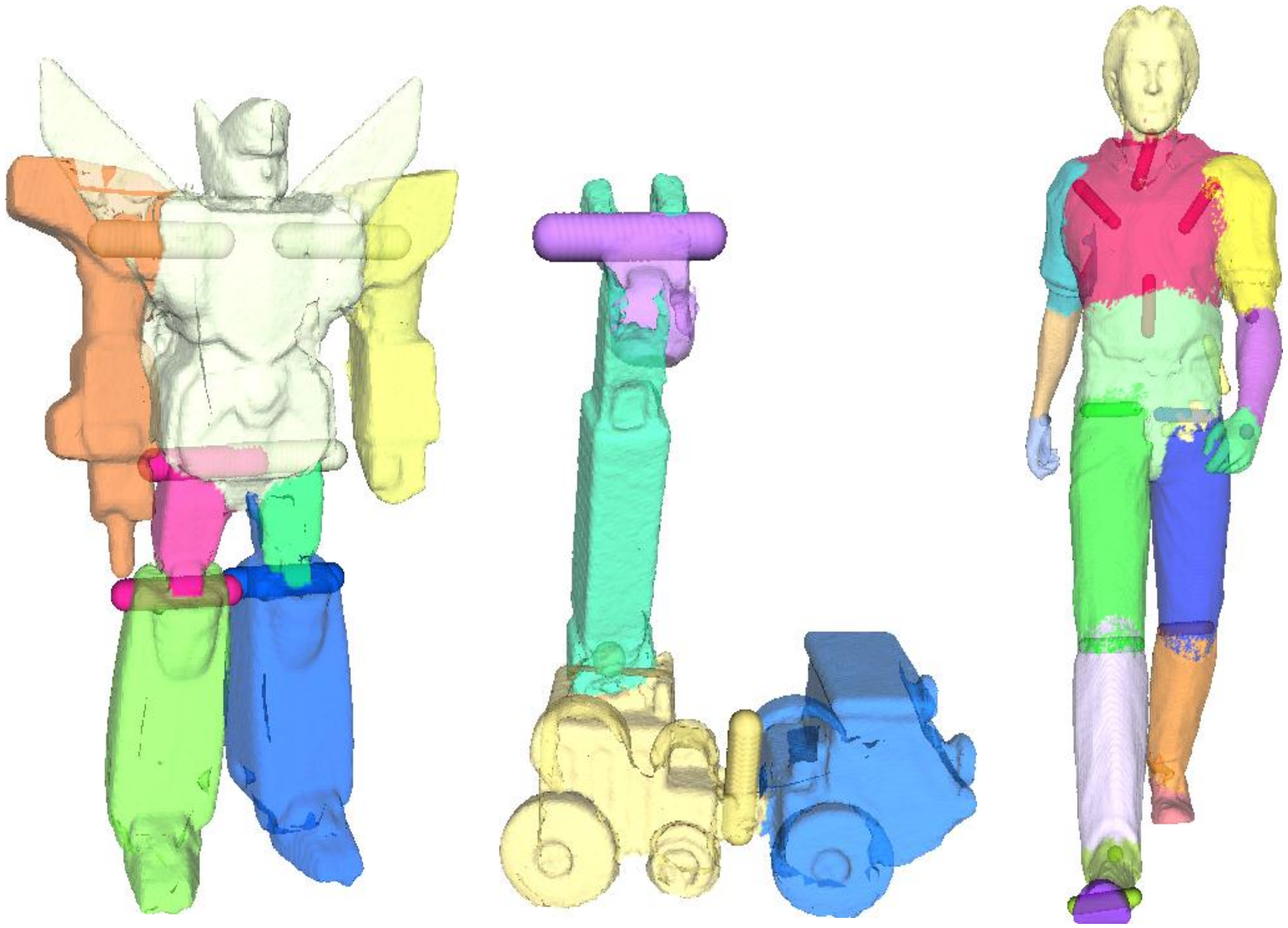
Transformation Optimization

- **Multi-part, multi-frame articulated Iterative Closest Point (ICP)**
  - Update closest point
  - Solve for transformation
  - Repeat until convergence
- **Gauss-Newton for non-linear least squares**

(Converged)

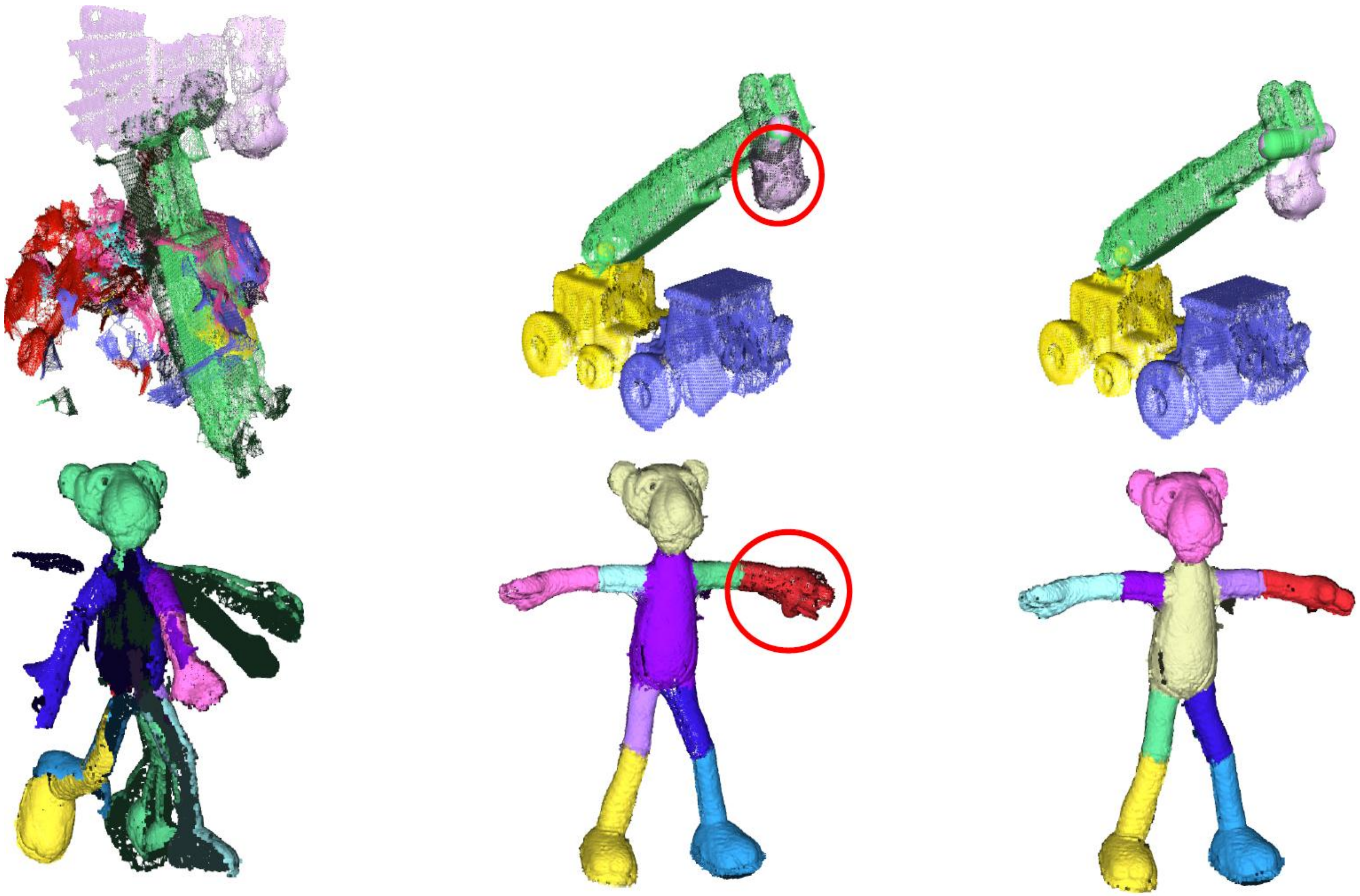
Joint Constraint

- **Prevents parts from separating**
- **Two types of joints**
  - Ball Joints (3 DOF)
  - Hinge Joints (1 DOF)
- **Derived from part boundaries**



Reconstructed Joints

Joint Constraint



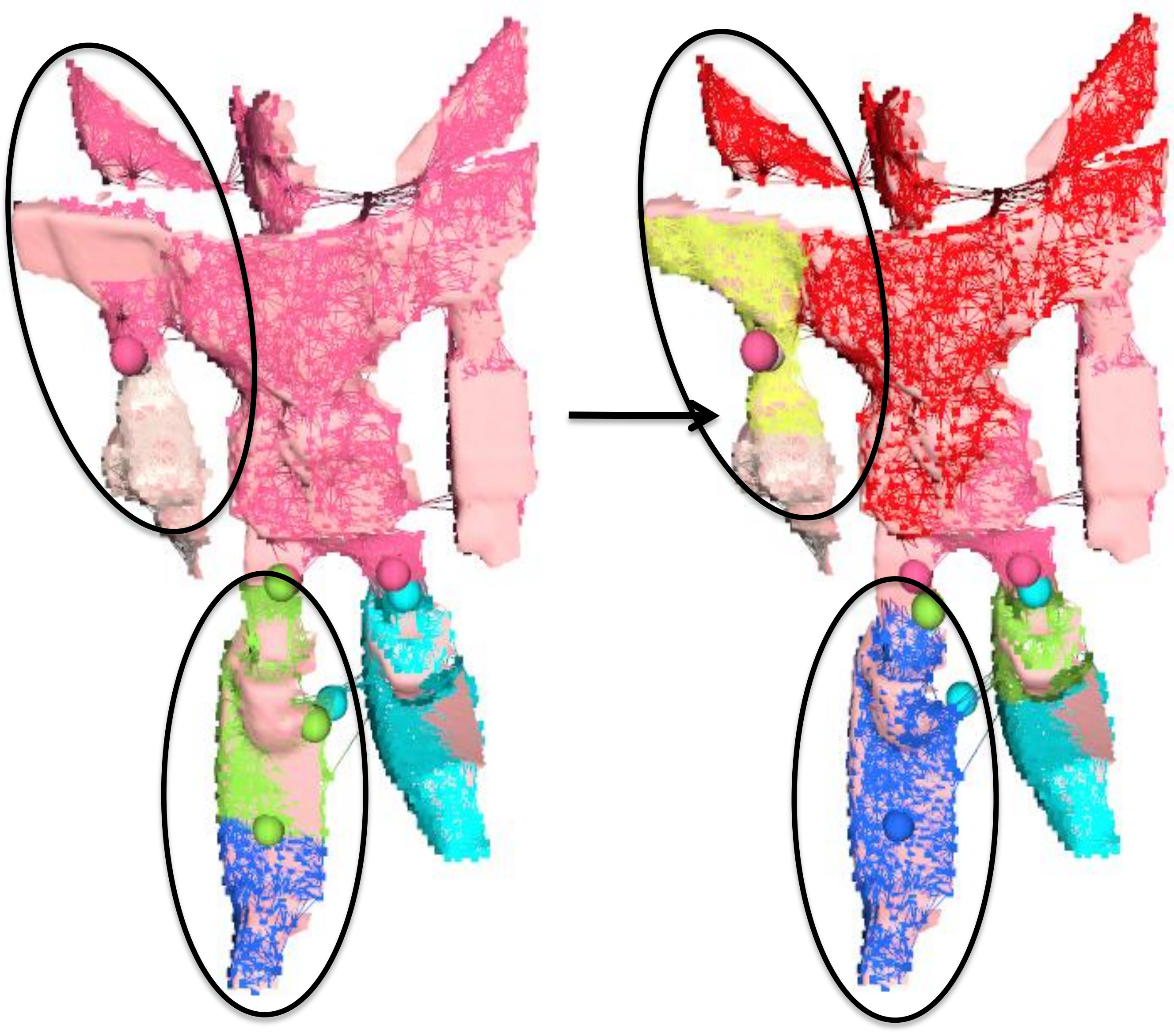
No Joints

Ball Joints Only

Ball and Hinge Joints

Label Optimization

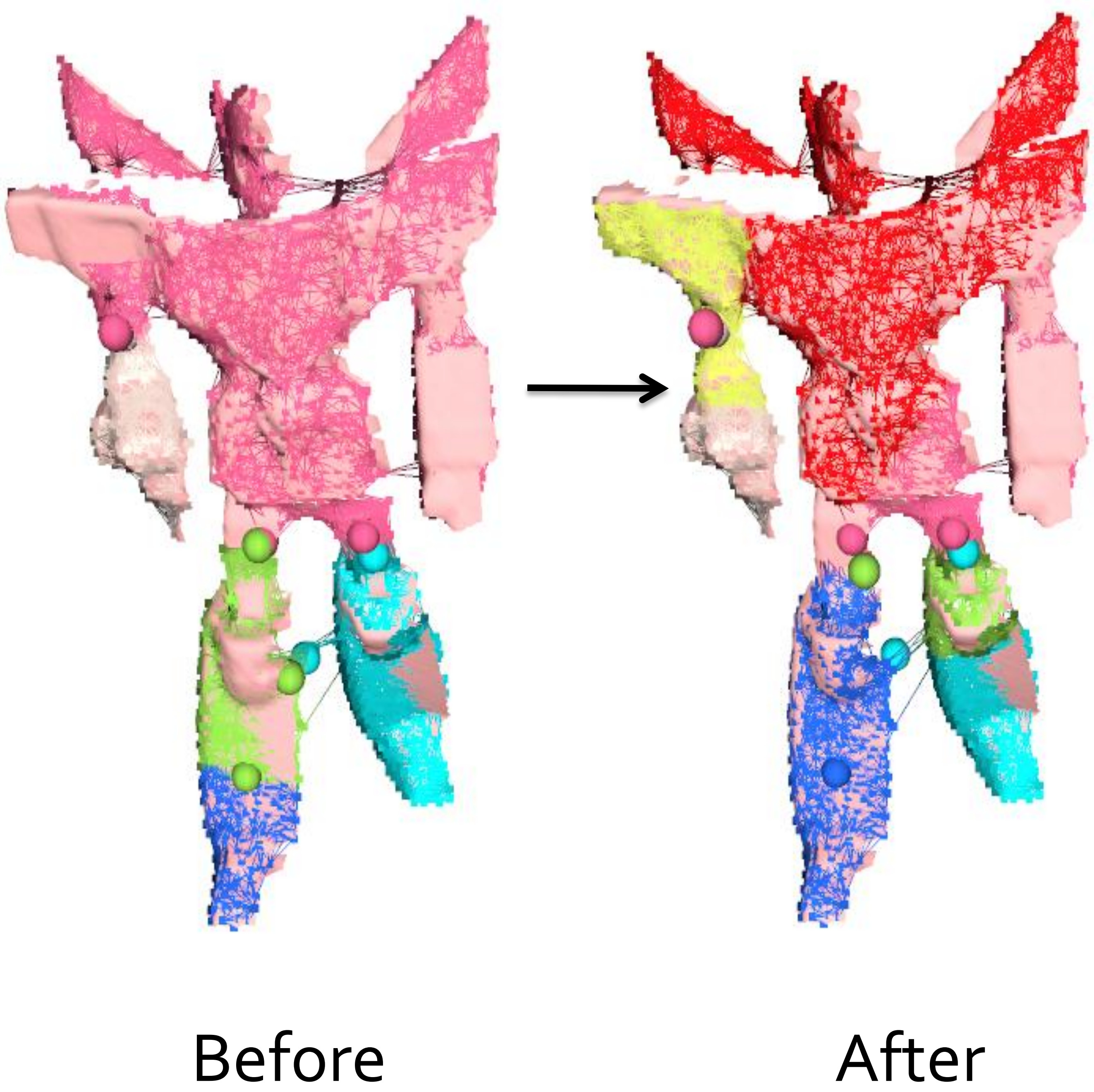
- **Change the labels to produce better alignment**
- **Transformations fixed**
- **Measure alignment using closest point distance**



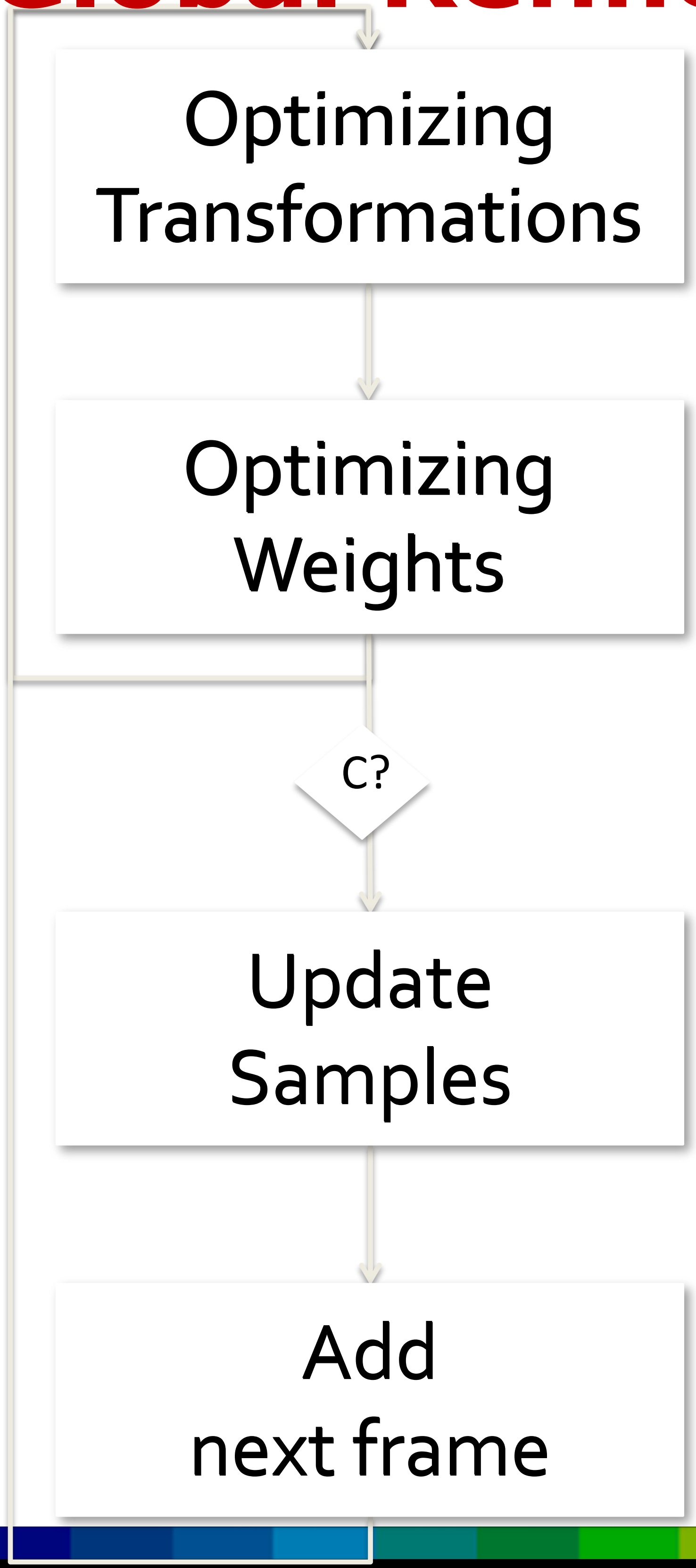
Before After

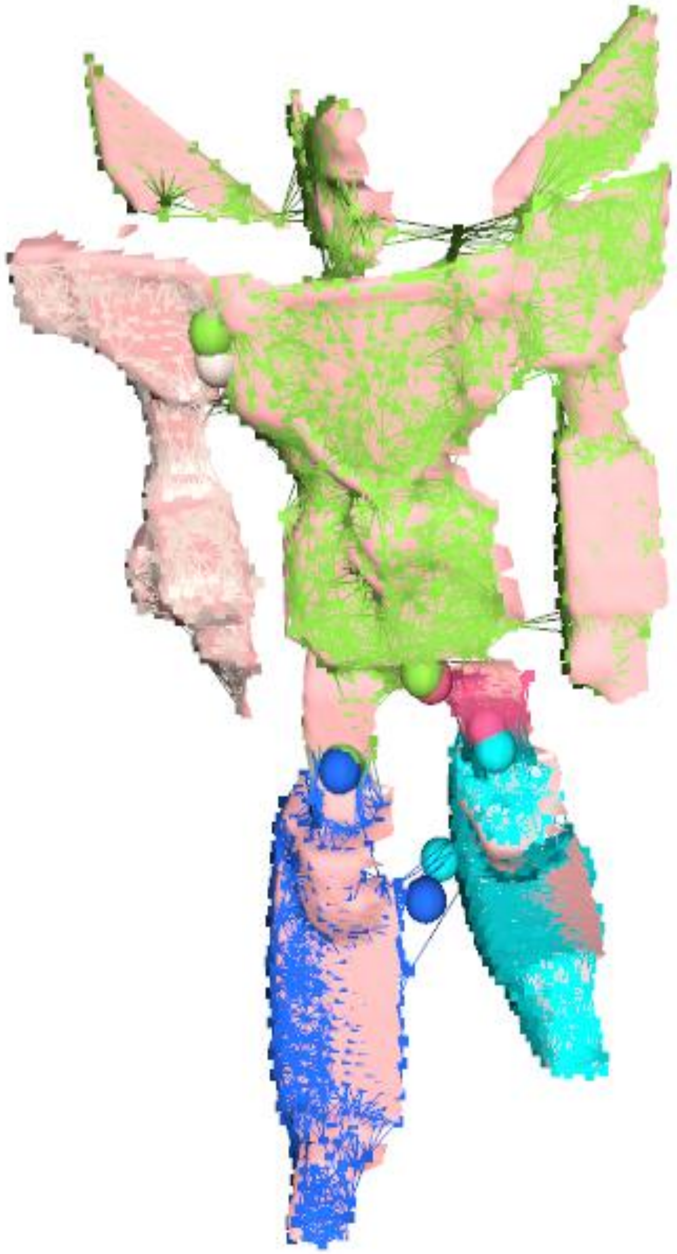
Label Optimization

- **Graph Cuts [Boykov et al. 2002]**
  - Data constraint: minimize distance
  - Smoothness constraint: consolidate labels



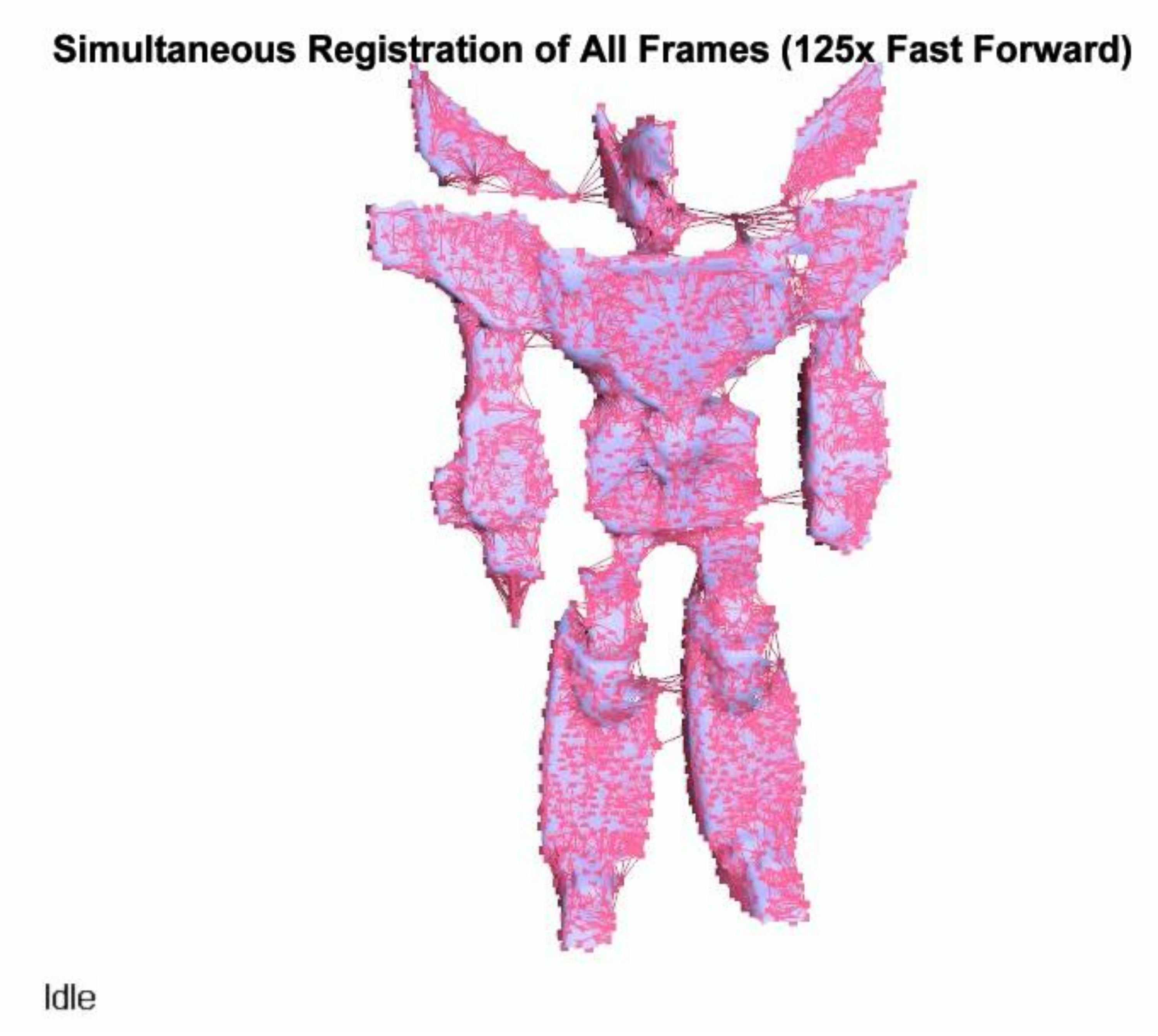
Global Refinement: Step Through





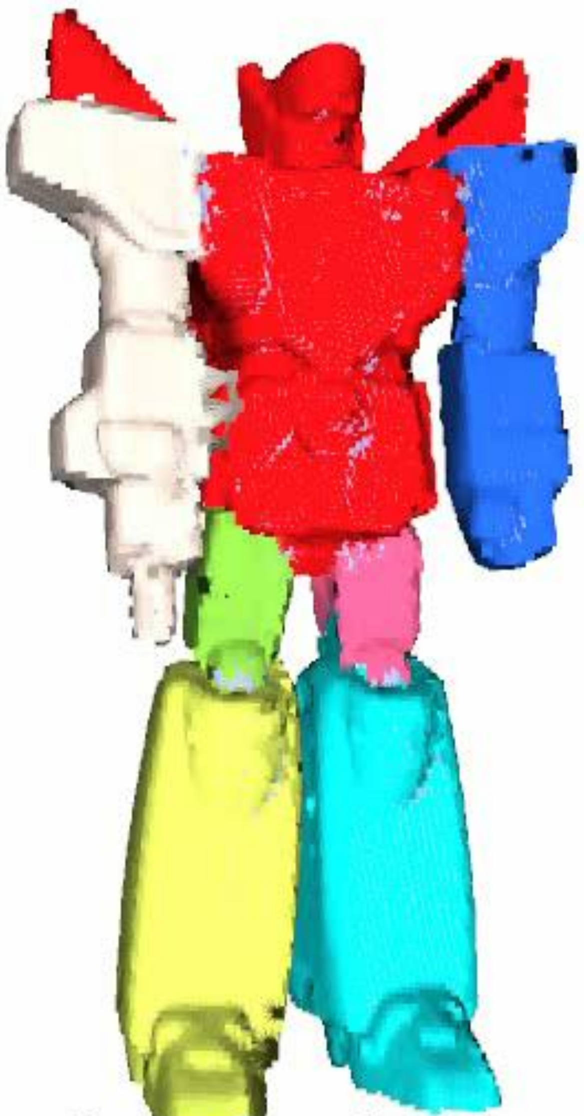
(Converged)

Global Refinement: Fast Forward



Post-processing

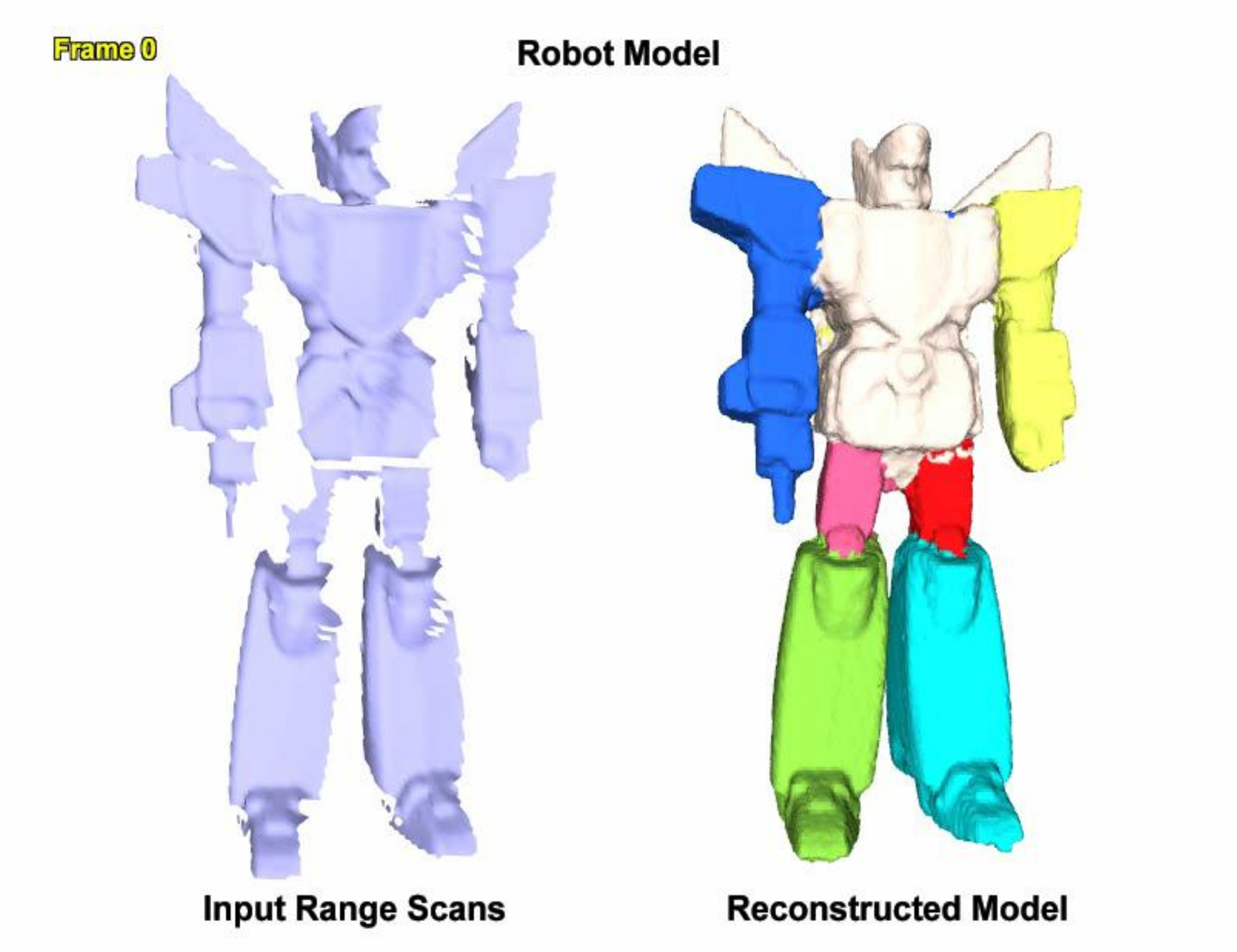
- Gather all frames into reference pose
- Resample surface, reconstruct mesh



Dense Sample Set

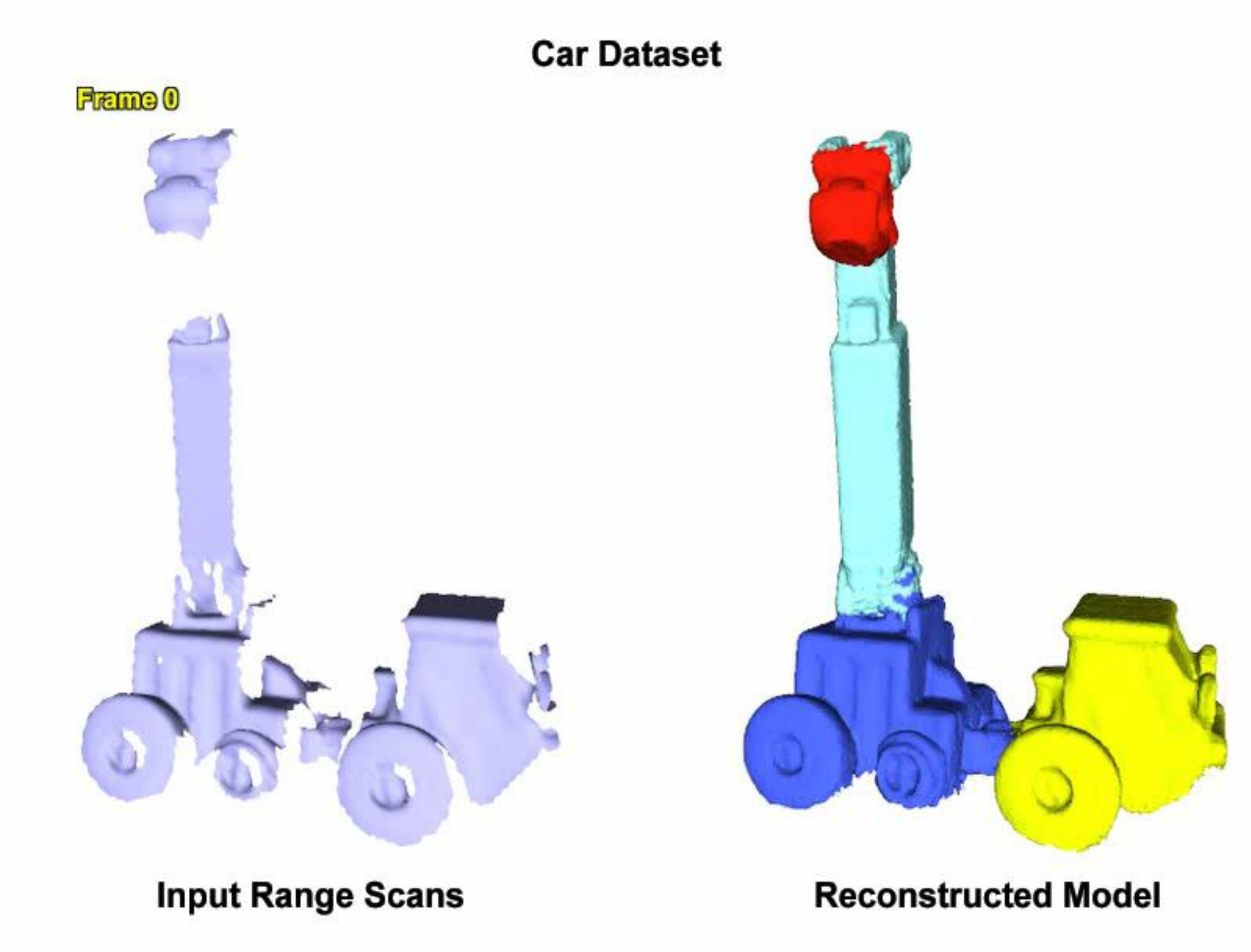
Results

Results: Registration



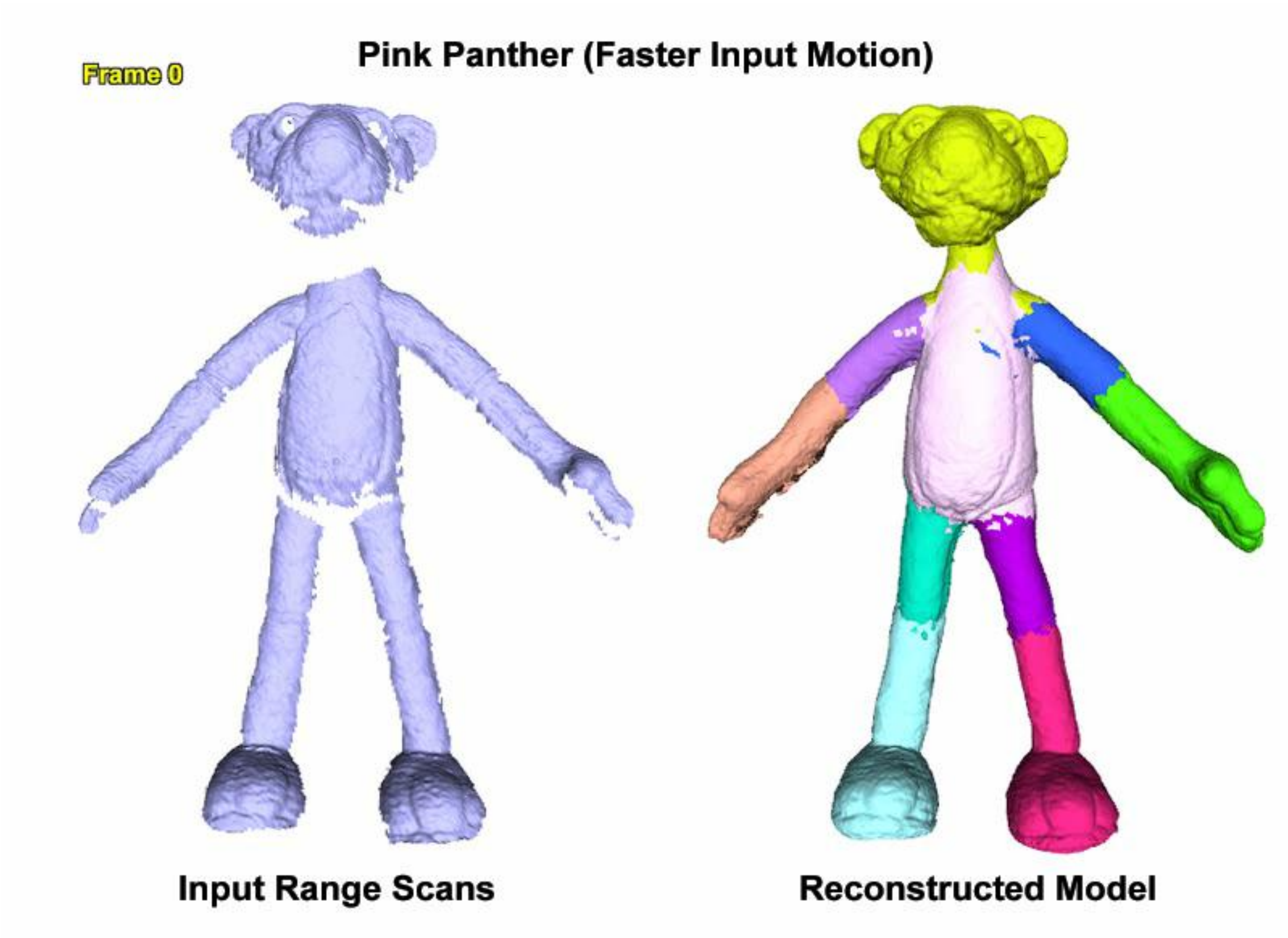
- Intel Xeon 2.5 GHz
- 90 Frames
- 7 Parts
- 0.84 million points
- 5000 DSG samples
- Total 165 mins
- 110 sec/frame

Results: Registration



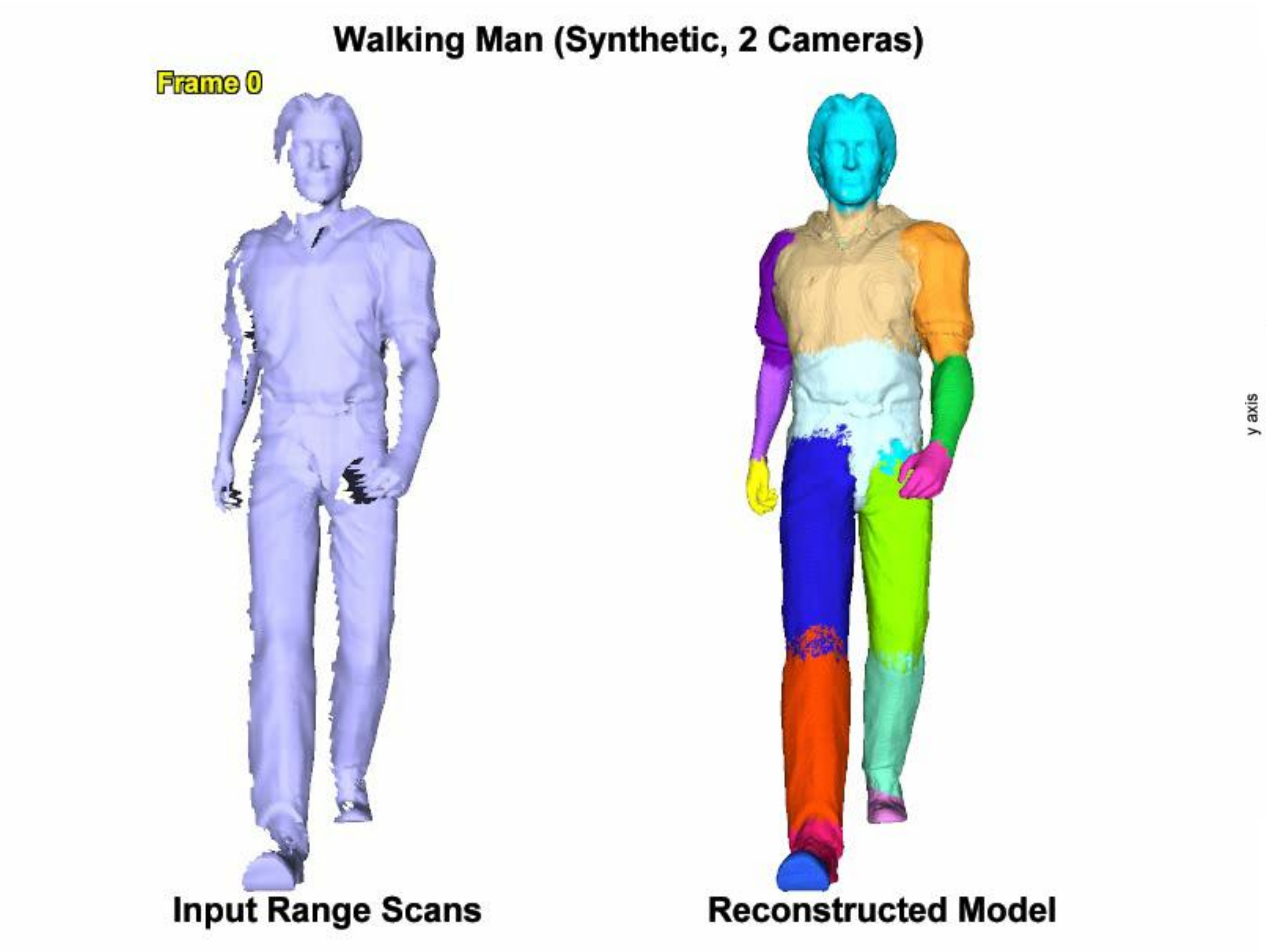
- Intel Xeon 2.5 GHz
- 90 Frames
- 4 Parts
- 0.48 million points
- 2700 DSG samples
- Total 66 mins
- 44 sec/frame

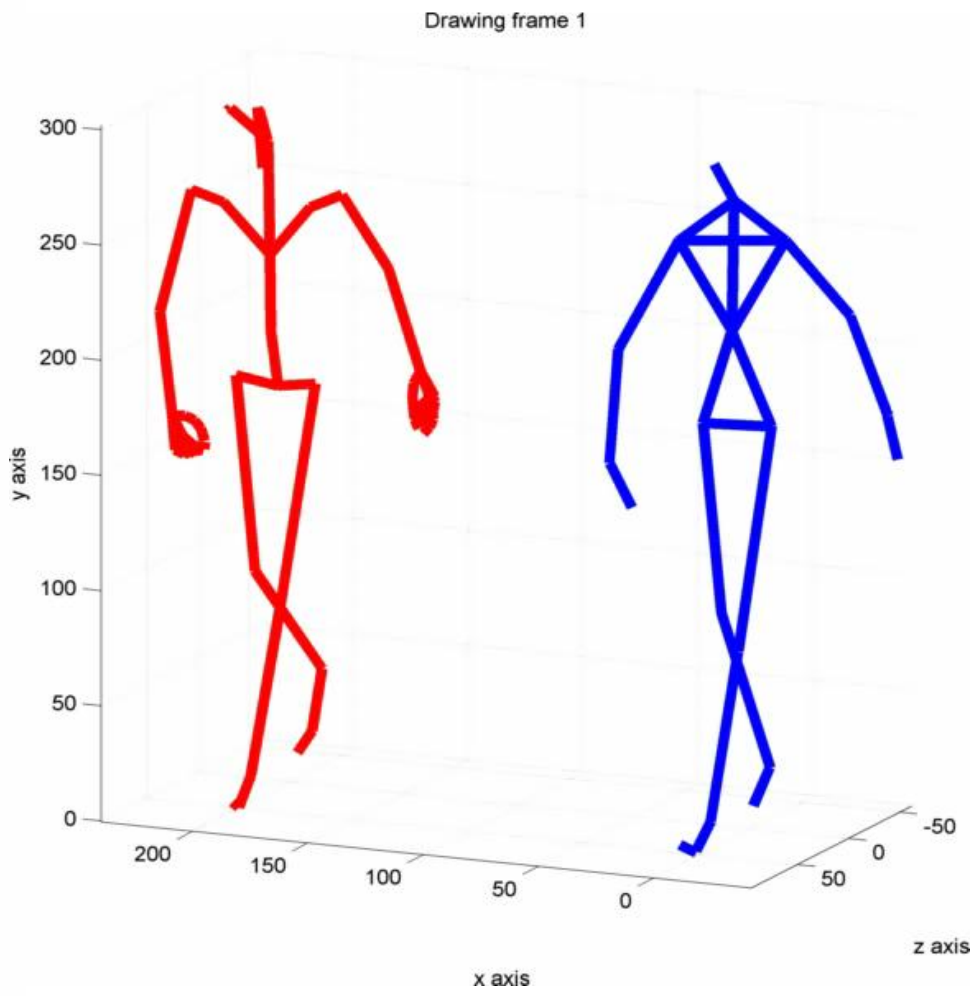
Results: Registration



- Intel Xeon 2.5 GHz
- 40 Frames
- 10 Parts
- 2.4 million points
- 4000 DSG samples
- Total 75 mins
- 113 sec/frame

Ground truth comparison

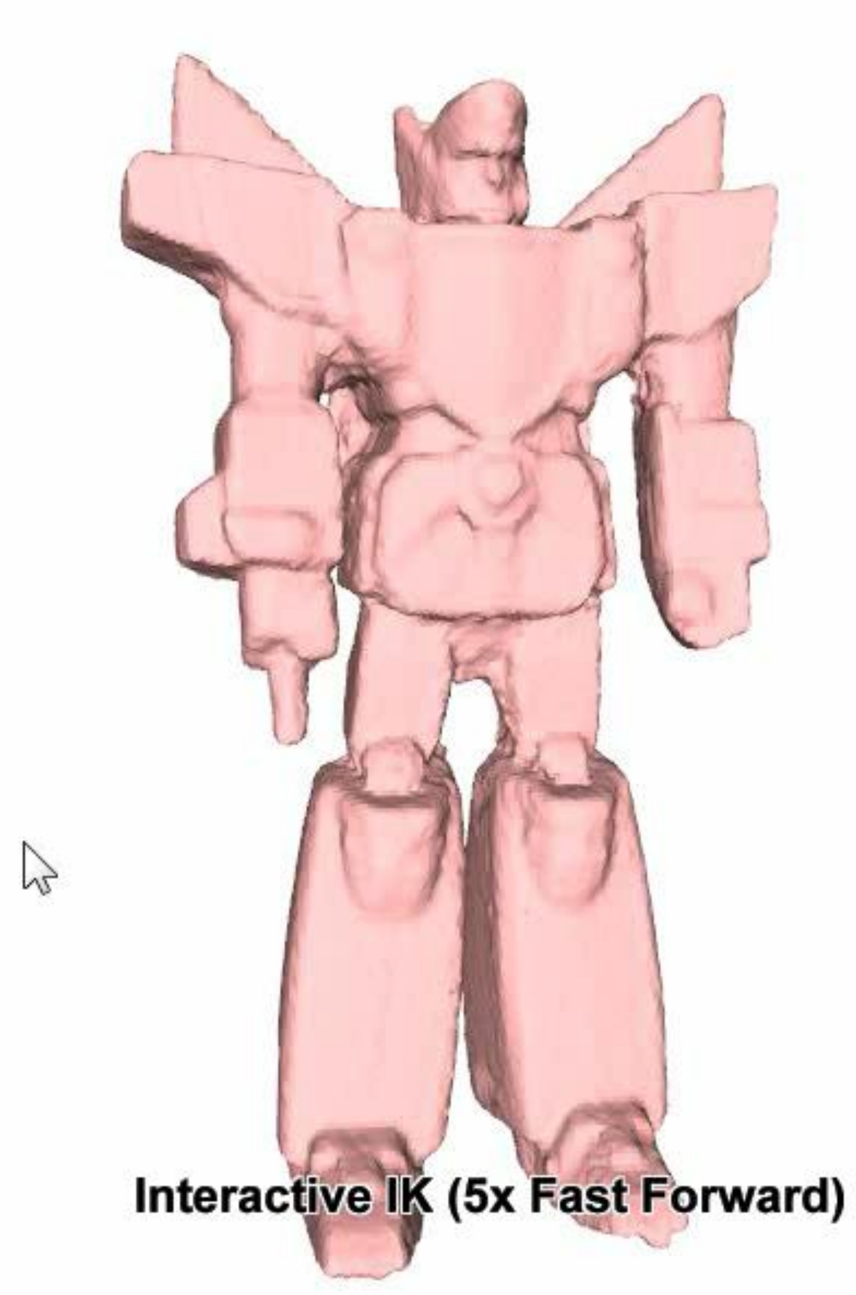




Red: Ground-truth

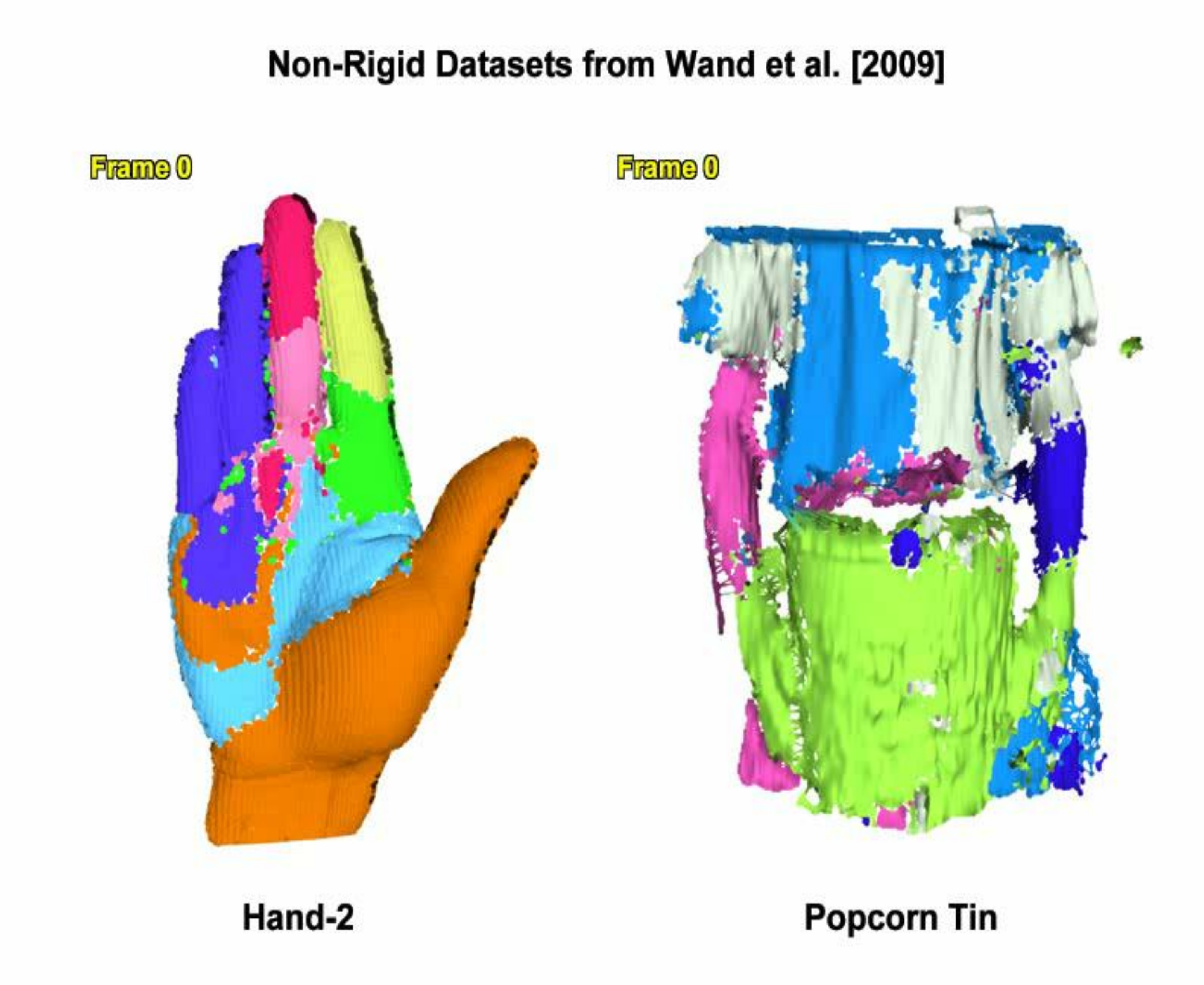
Blue: Reconstructed

Results: Inverse Kinematics



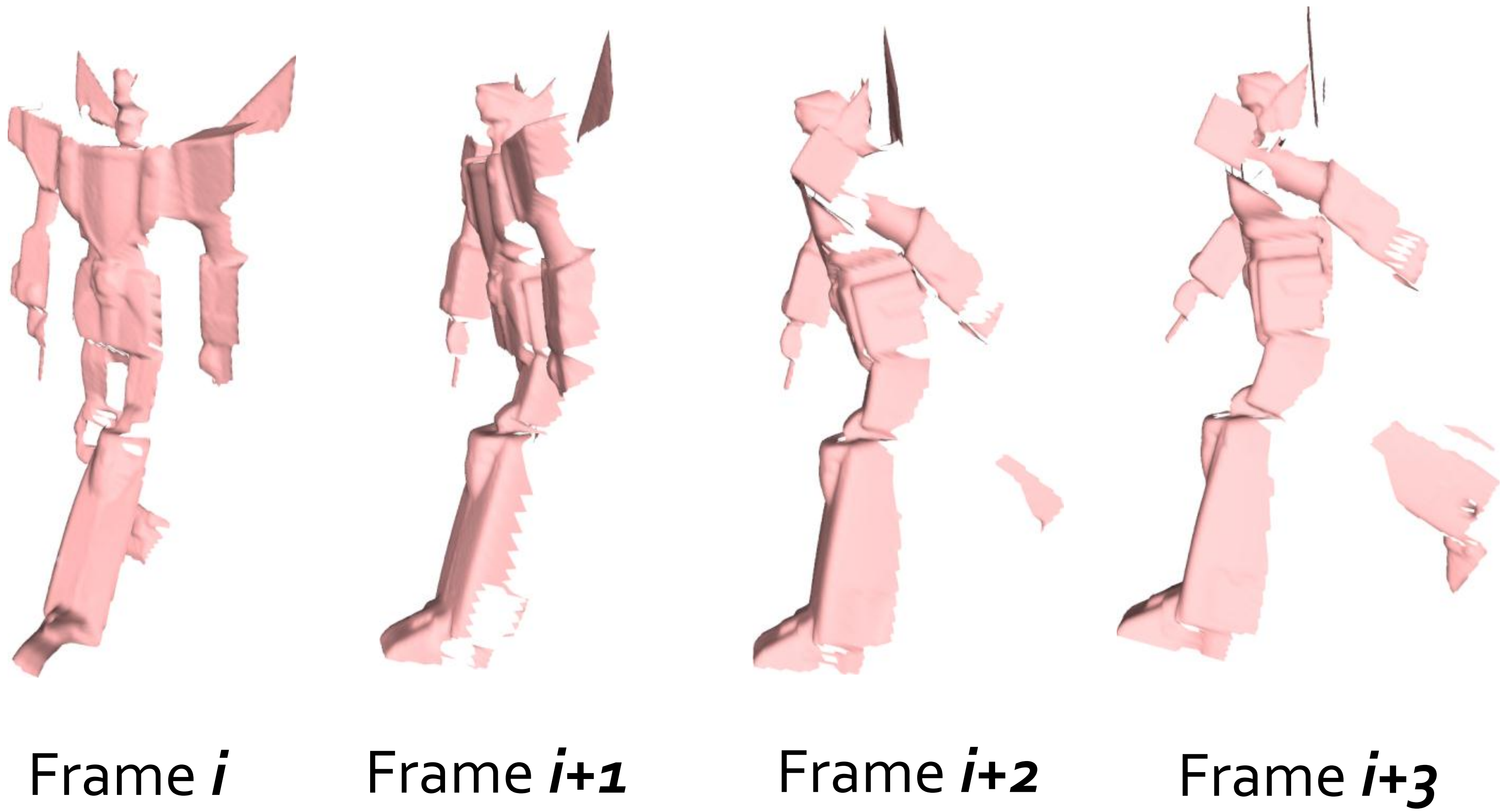
Limitations

Piecewise rigid approximation



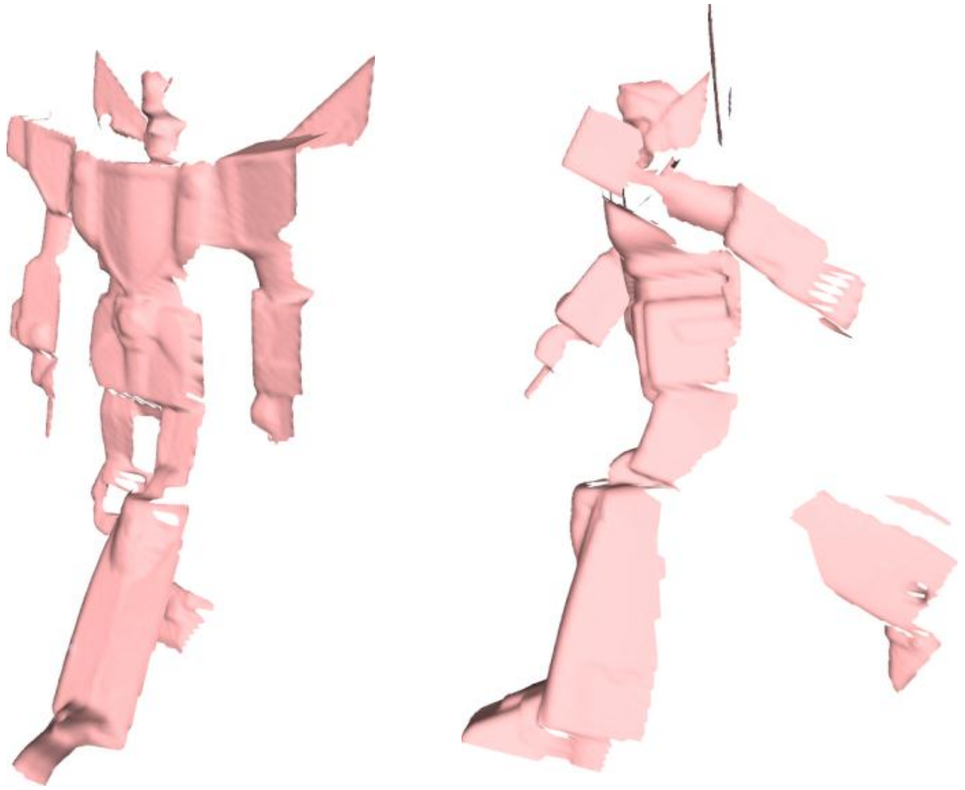
Limitations

Needs sufficient overlap



Limitations

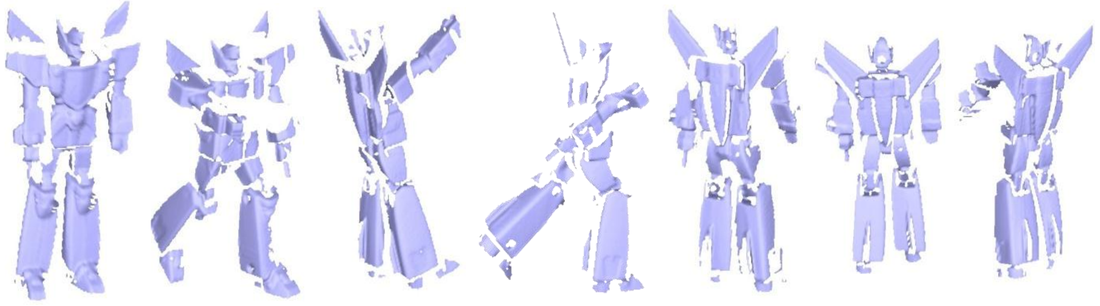
Needs sufficient overlap



Frame *i* Frame ***i+1***

Conclusions

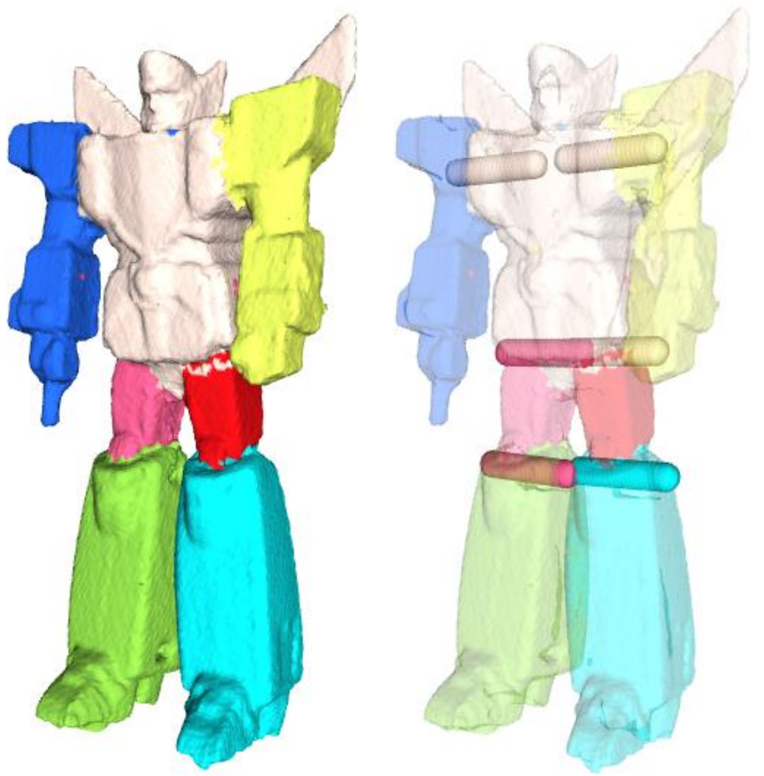
Articulated Global Registration



Input Range Scans

Contributions

- Automatic registration algorithm for dynamic subjects
- No template, markers, skeleton, or segmentation needed
- Final result used directly to produce new animations



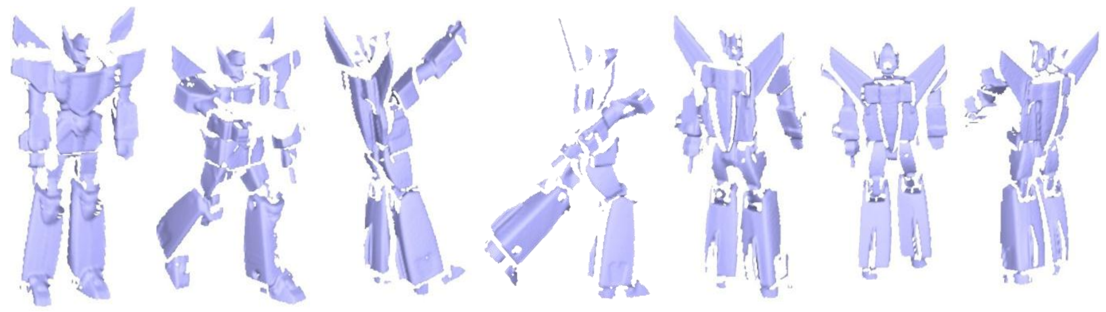
Reconstructed Poseable 3D Model

Future Work

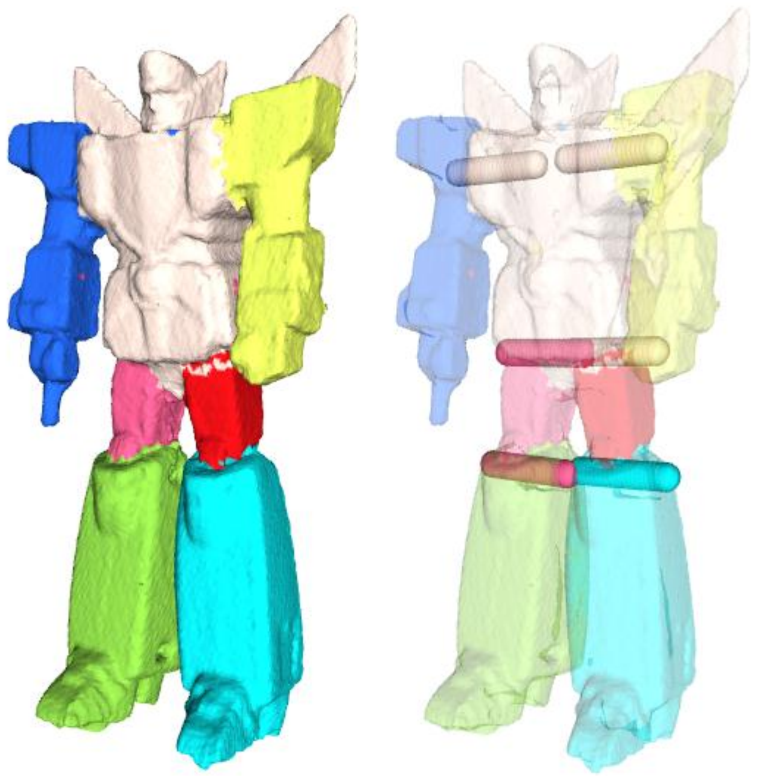
Add non-rigid motion

Reduce parameters

Real-time



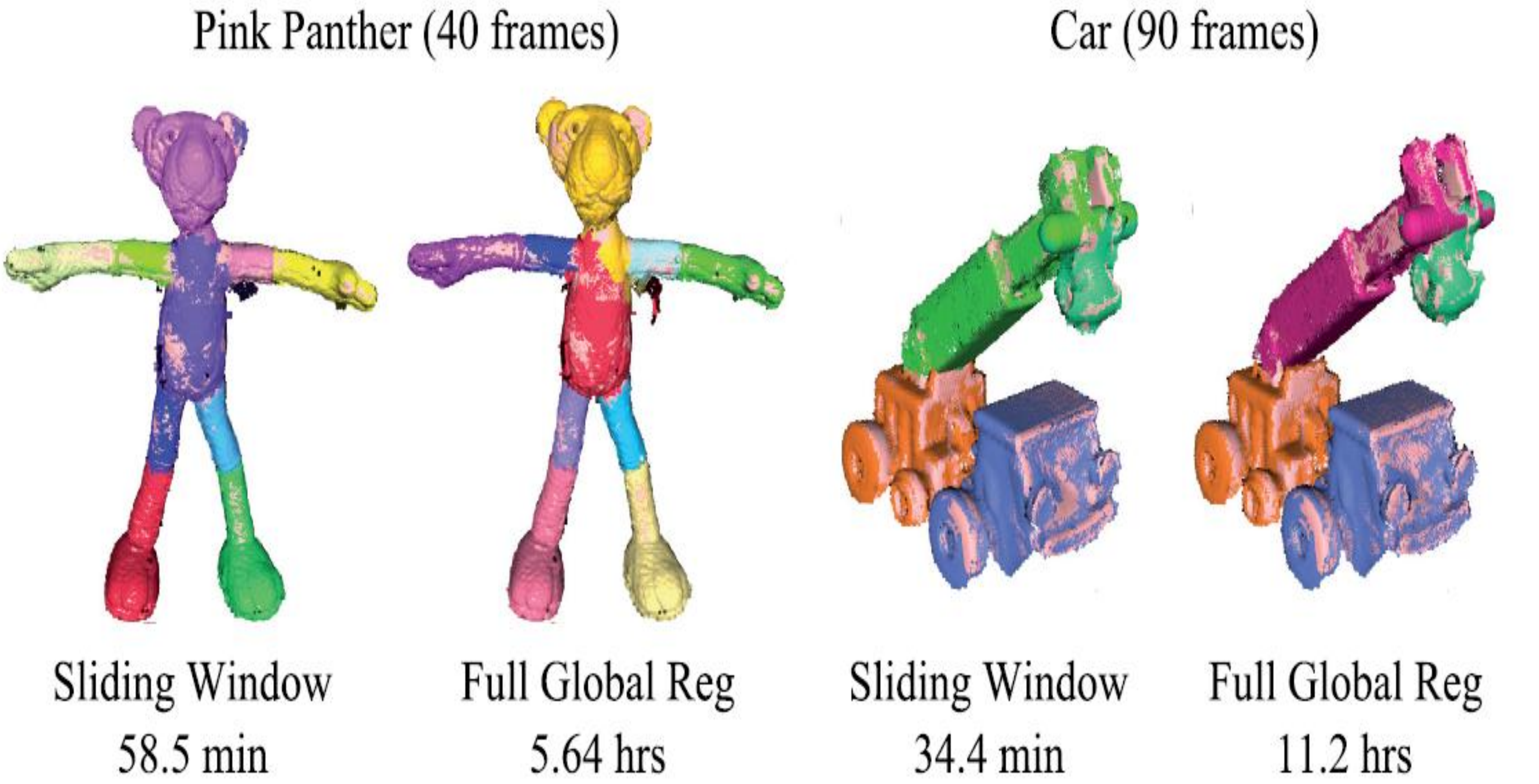
Input Range Scans



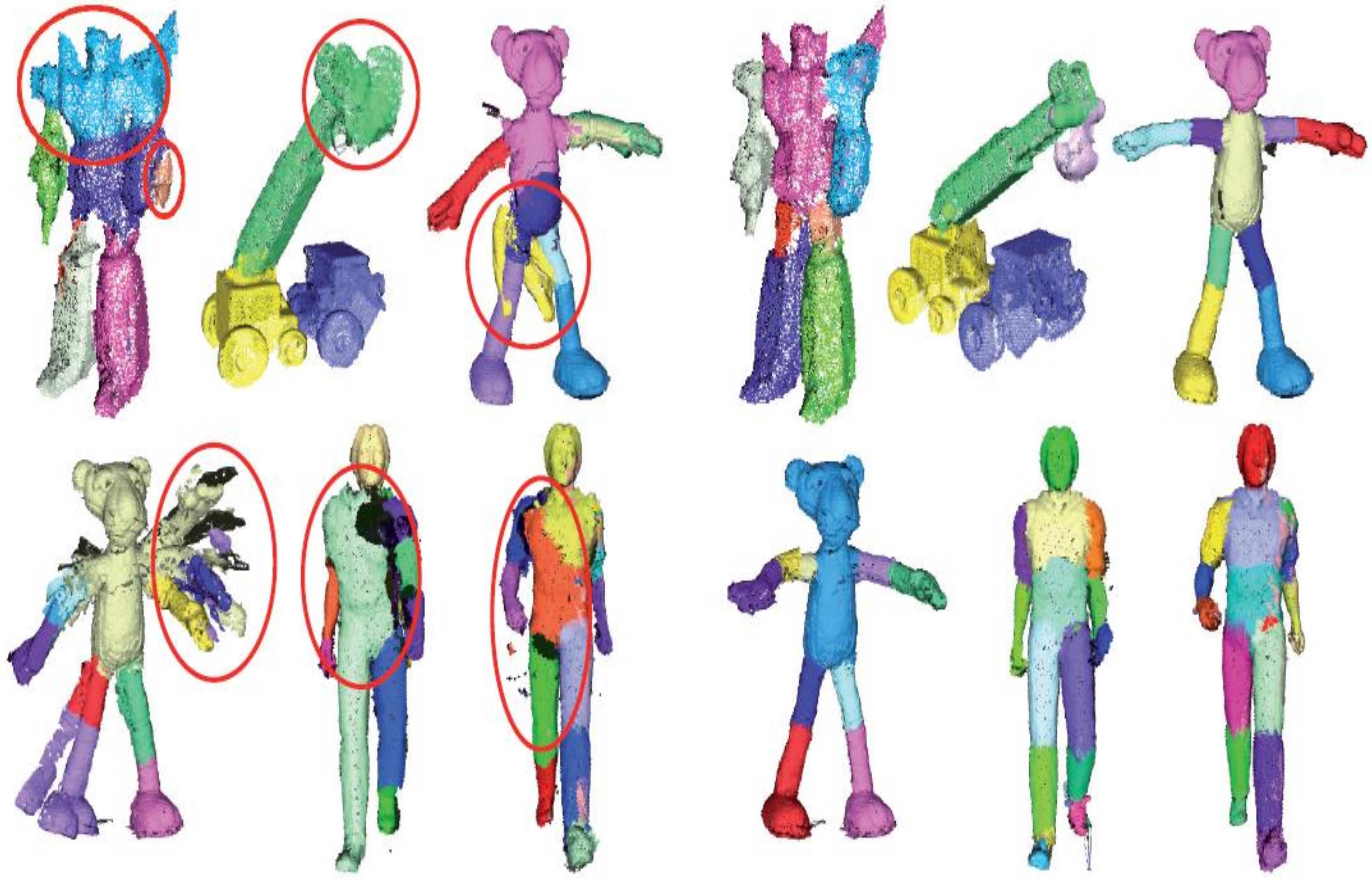
Reconstructed Poseable 3D Model

Additional Comparisons

Sliding window comparison



Local vs. global comparison



(a) Using sequential registration (b) Using simultaneous registration