Characterizing and Monitoring Children in Vehicles

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“Normally Positioned” Children?

- Most restraint system testing assumes normally positioned children:
  - Symmetrical posture
  - Torso against seat back
  - Belt well positioned

- Field and experimental data show other postures are common:
  - Normally riding postures vary widely
  - Crash-avoidance maneuvers affect postures

Stockman 2016

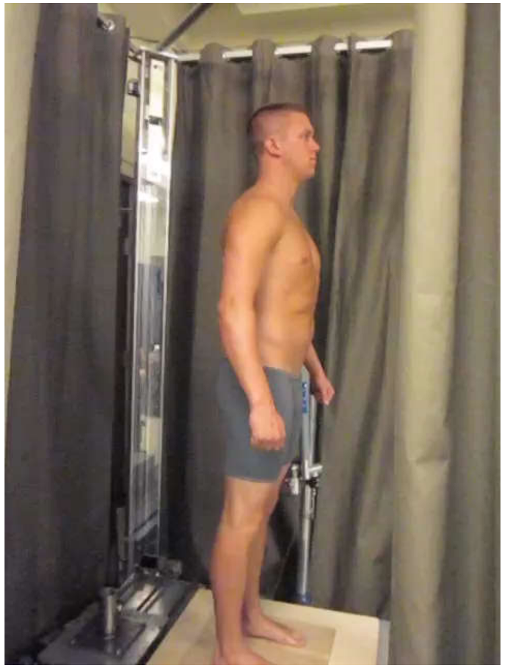
Long-Term Objectives

1. Develop research tools for quantifying occupant behaviors in vehicles
   → extended duration, automated data collection and reduction
   → "good" accuracy and precision

2. Develop and deploy production systems to characterize and monitor occupants
   → adapt restraint systems for occupant characteristics and posture
   → intervene to improve occupant pre-crash posture
   → Modulate automated vehicle performance based on occupant factors, including during pre-crash manevers

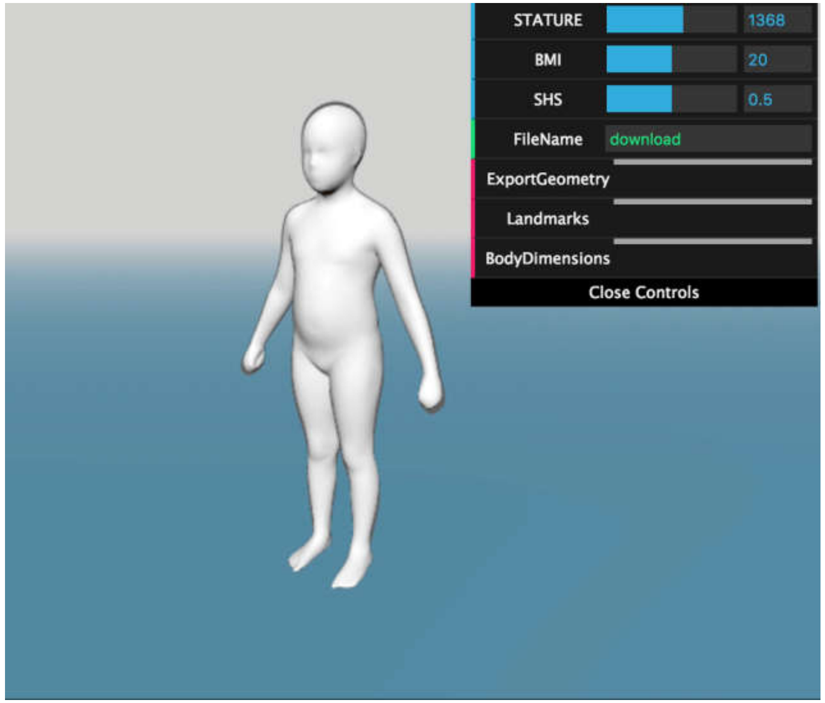
Body Shape Measurement and Modeling

http://humanshape.org/



Laser Scanner

Sample Scans



Body Shape Models

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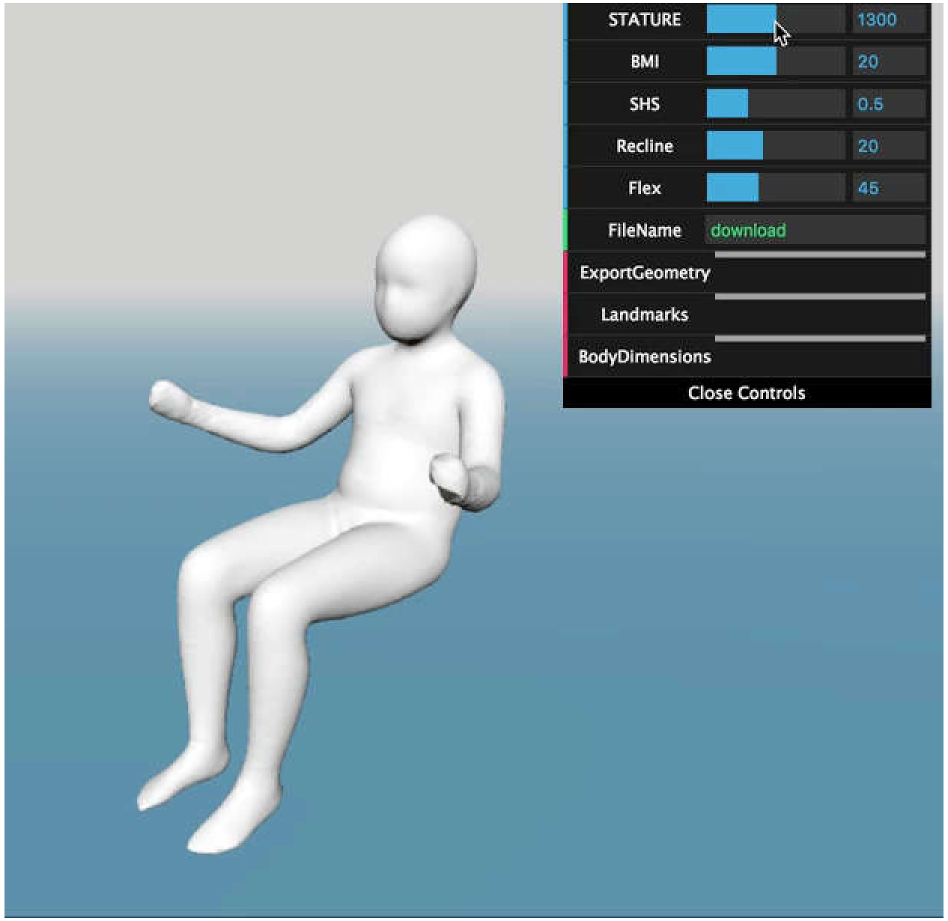
Park, B-K and Reed, M.P. (2015). Parametric body shape model of standing children ages 3 to 11 years. *Ergonomics*, 58(10):1714-1725. 10.1080/00140139.2015.1033480

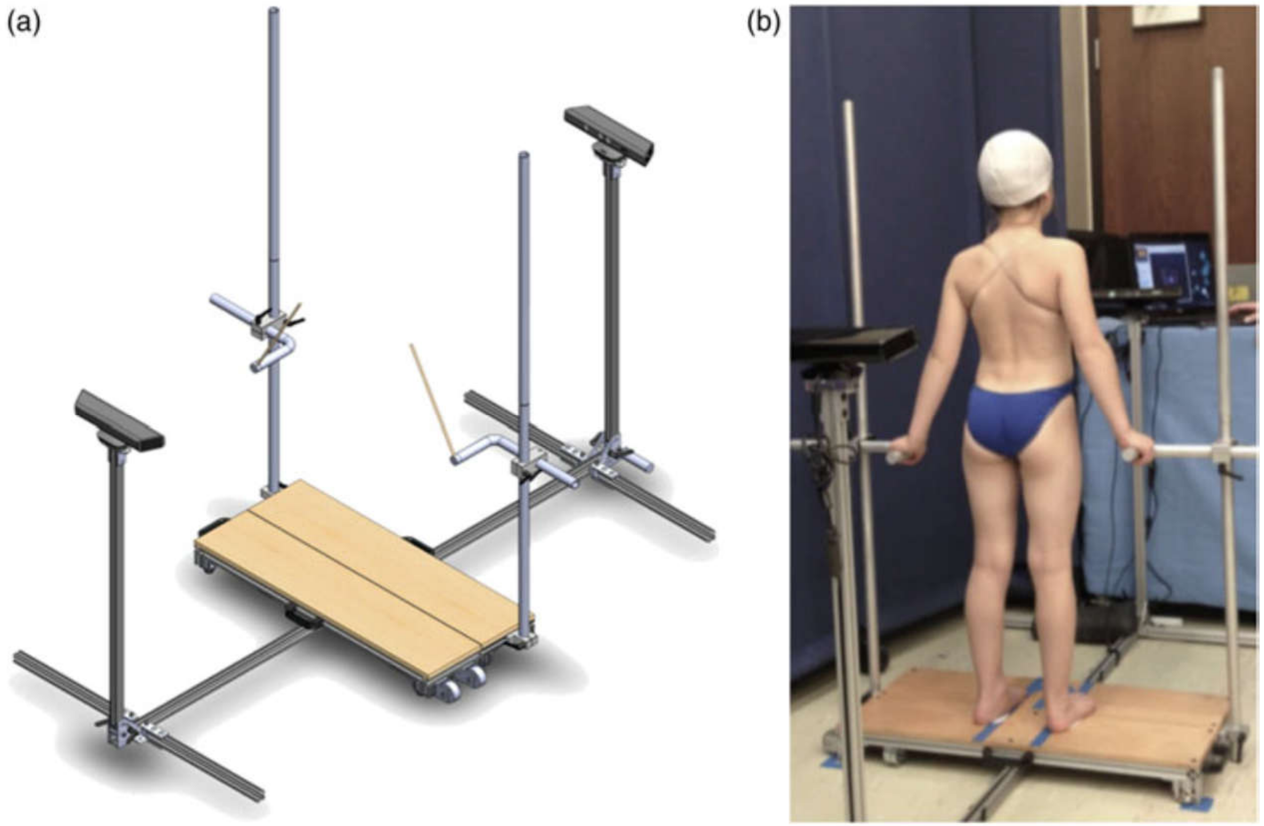
Seated Child Body Shape Model

Based on laser scans from 140 children ages 3 to 11 years



Park, B-K D., Ebert, S., and Reed, M.P. (2017). A parametric model of child body shape in seated postures. Traffic Injury Prevention. 18(5):533-536

Child Scanning With Microsoft Kinect Sensor (Xbox)



Park, B-K, Lumeng, J.C., Lumeng, C.N., Ebert, S.M., and Reed, M.P. (2014). Child body shape measurement using depth cameras and a statistical body shape model. *Ergonomics*, 58(2):301-309. 10.1080/00140139.2014.965754

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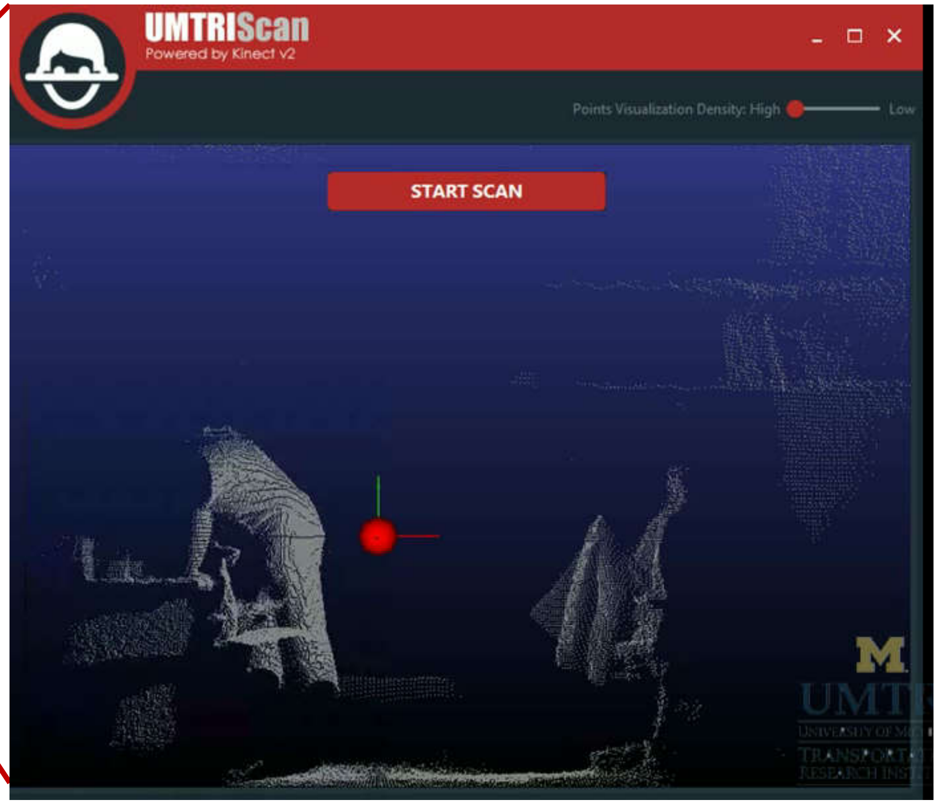
Scanning Subject: Kinect V2

- Simple hardware configuration for scanning: 1 sensor + 1 laptop
- Takes 3 scans of individual from 3 views (front, side and back)

Hardware configuration for scanning



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Inscribed Fitting Methods

Fit body shape model inside scan data to estimate body size and shape under clothing

Gender: 0.48
AgeAtTesting: 8.39
Weightkg: 30.22
Stature: 1307.86
ErectSittingHeight: 690.42
SHS: 0.53
BMI: 17.23
EyeHeight: 609.64
AcromialHeight: 430.25
KneeHeight: 407.78
TragionToTopOfHead: 124.50
HeadLength: 180.96
HeadBreadth: 145.96
Shoulder-ElbowLength: 270.69
Elbow-HandLength: 347.79
MaxHipBreadth: 253.15
Buttock-KneeLength: 441.18
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ChestCircumference: 670.44
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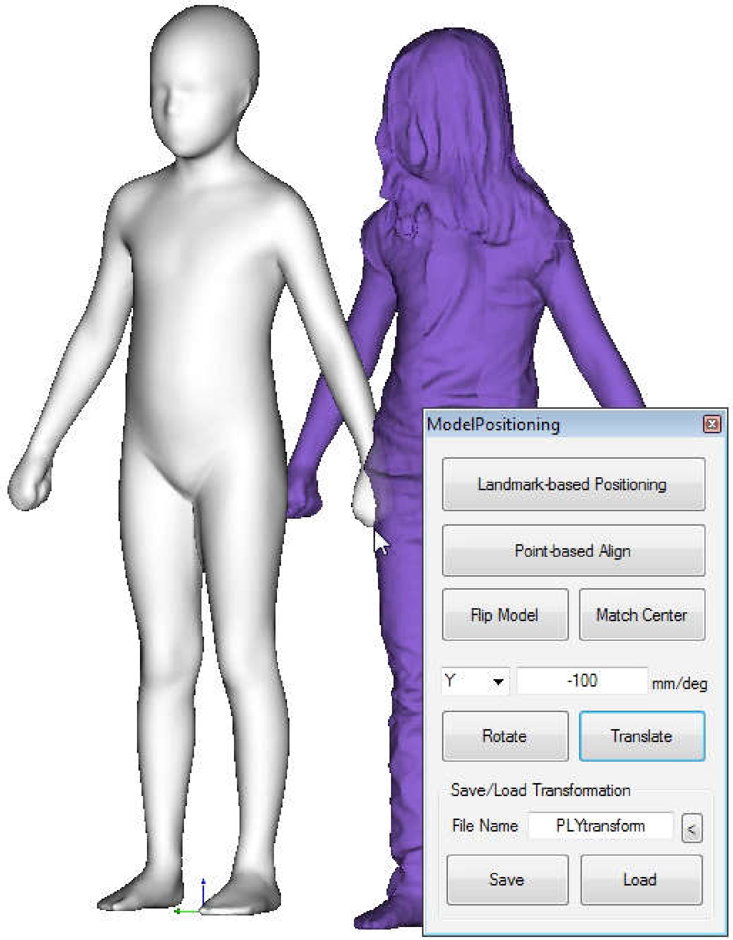

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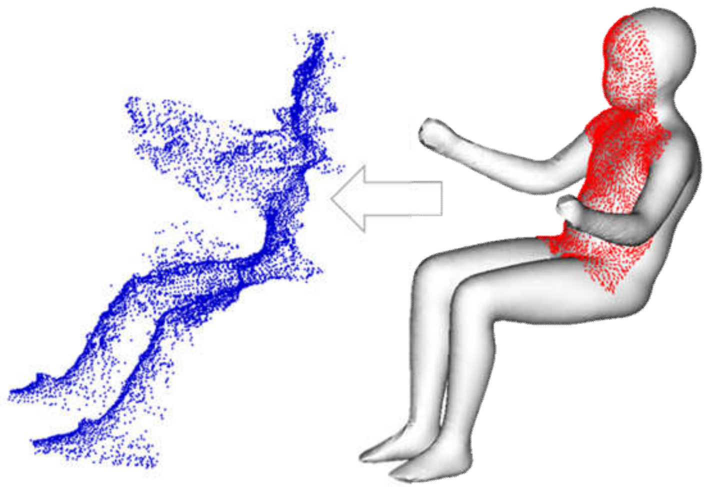
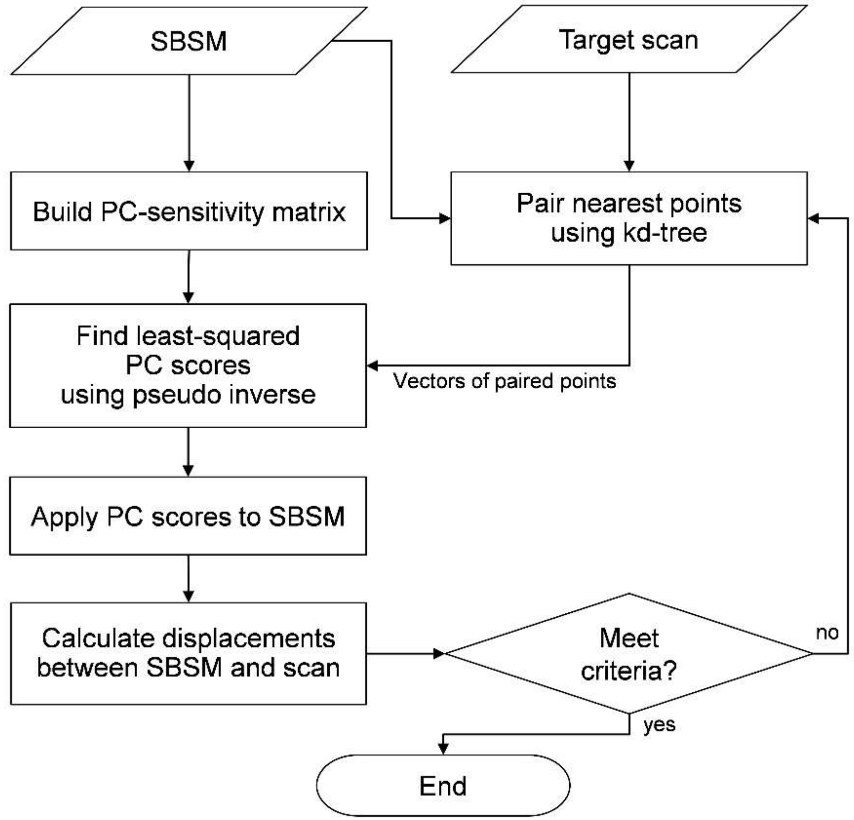
Seated Posture Fitting with Kinect v2

- Only frontal torso part of the model is fitted to target Kinect depth data
- Corresponding vertex pairs are found using an iterative closest point (ICP) technique



Kinect depth data Body shape model

Fitting Procedure Schematic



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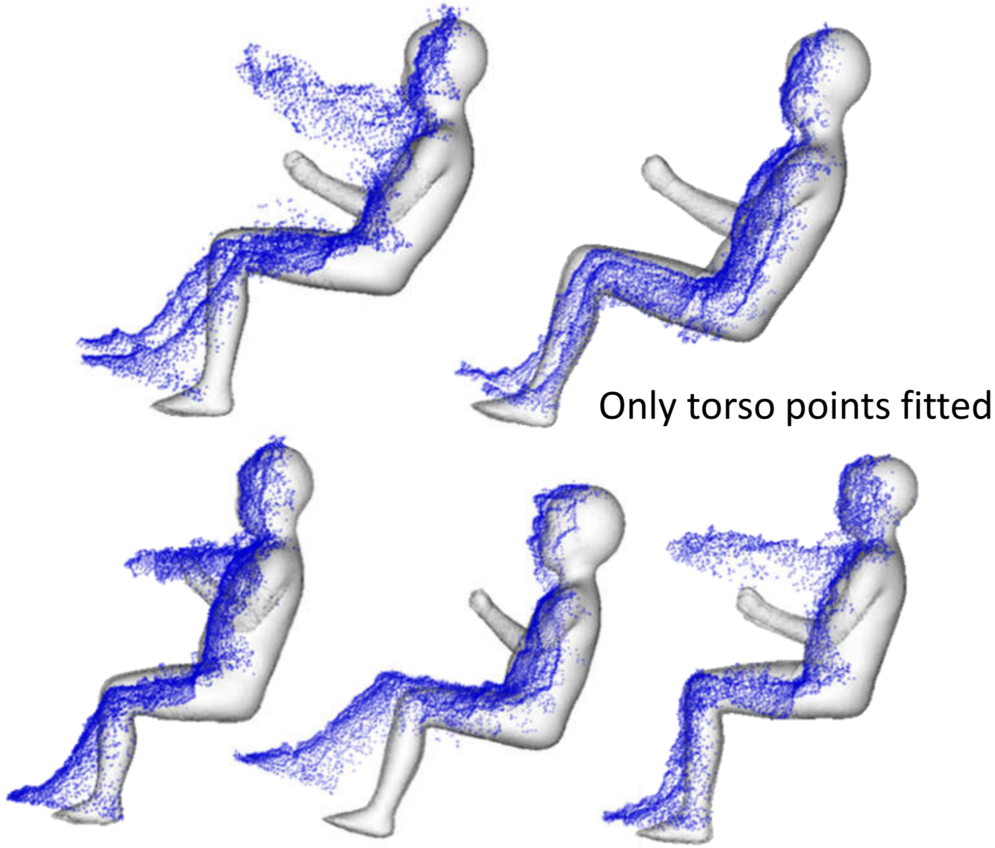
Seated Posture Fitting with Kinect v2 (Pilot)

- Fitted manikins were compared to the measured actual anthropometric data and laser scans
- Stature estimated from the Kinect-fitted models was the most accurately predicted variable (Pearson correlation coefficient of 0.89 and RSME of 57.6 mm).
- The BMI and weight were estimated somewhat higher than the true values.
- RMSE for six participants was 23.6 mm, and the Pearson correlation coefficient was 0.964.



Park, B-K.D. and Reed, M.P. (2017). Characterizing Vehicle Occupant Body Dimensions and Postures Using a Statistical Body Shape Model. SAE Technical Paper 2017-01-0497. SAE International, Warrendale, PA

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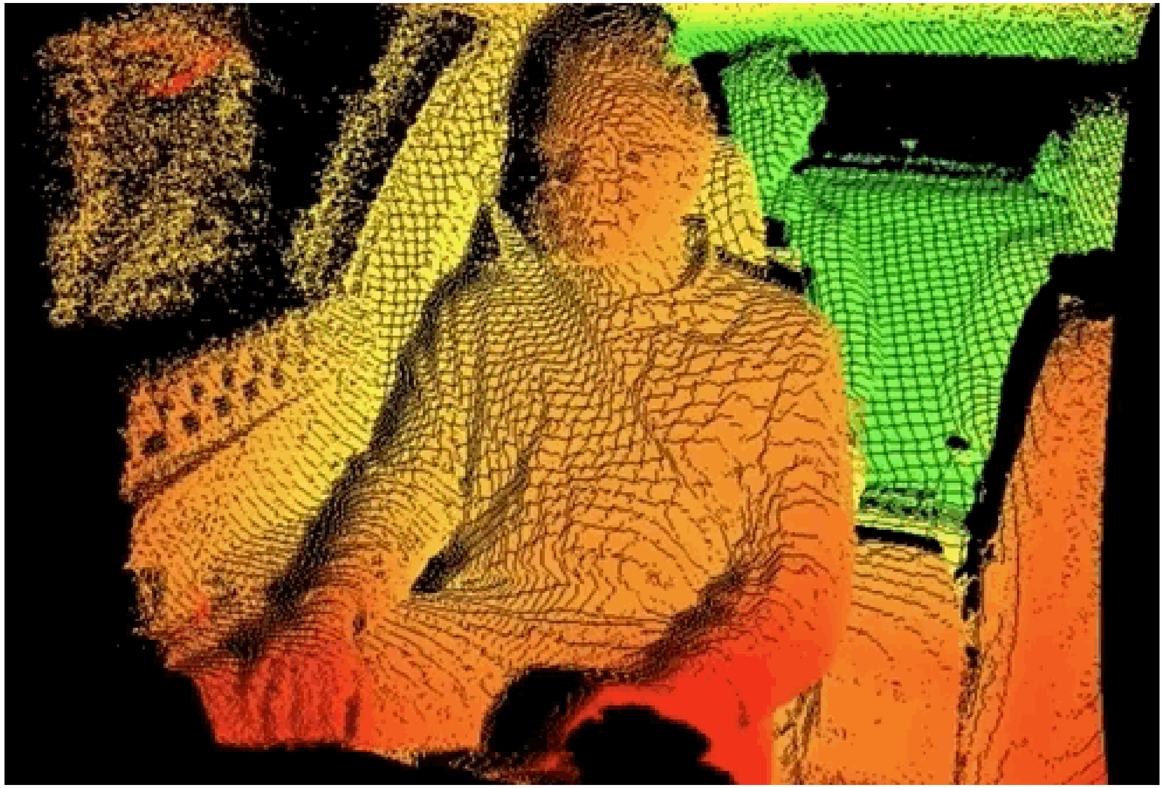
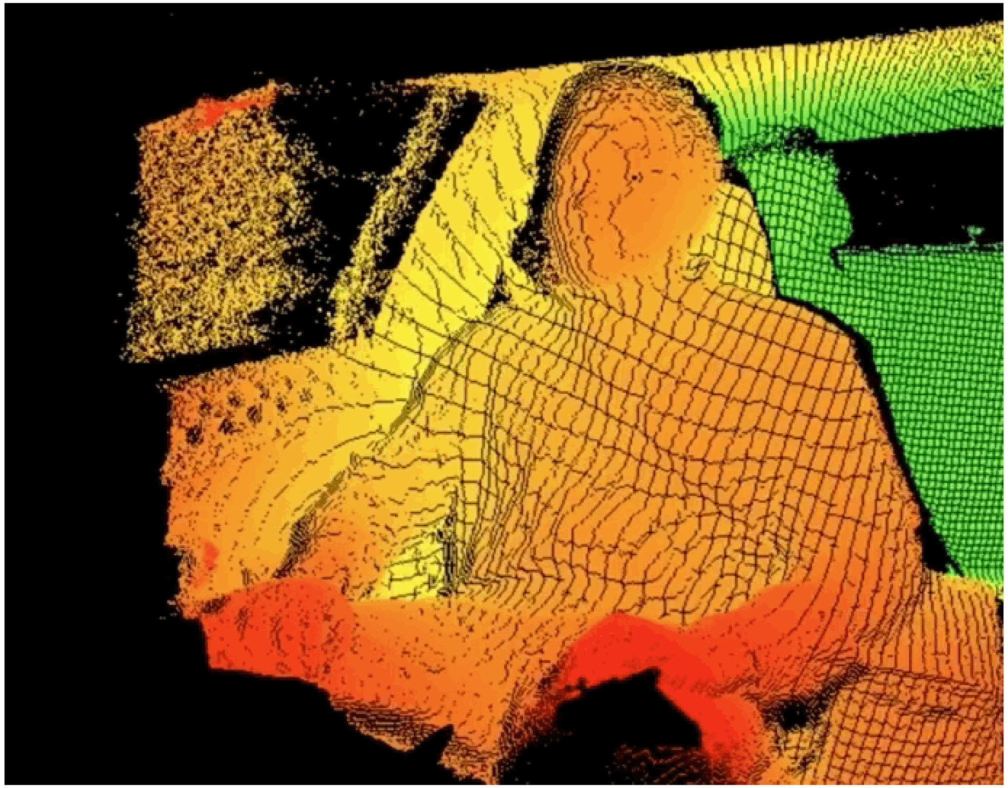
Tracking Motions in Dynamic Events





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Head Tracking

- Accurately track head orientation and location by fitting a head model to depth data
- The fitting method can be further improved by detecting facial features, i.e., nose tip
- Speed will be enhanced by analyzing frames in sequence and through kinematic prediction

Subject-specific head model fitting

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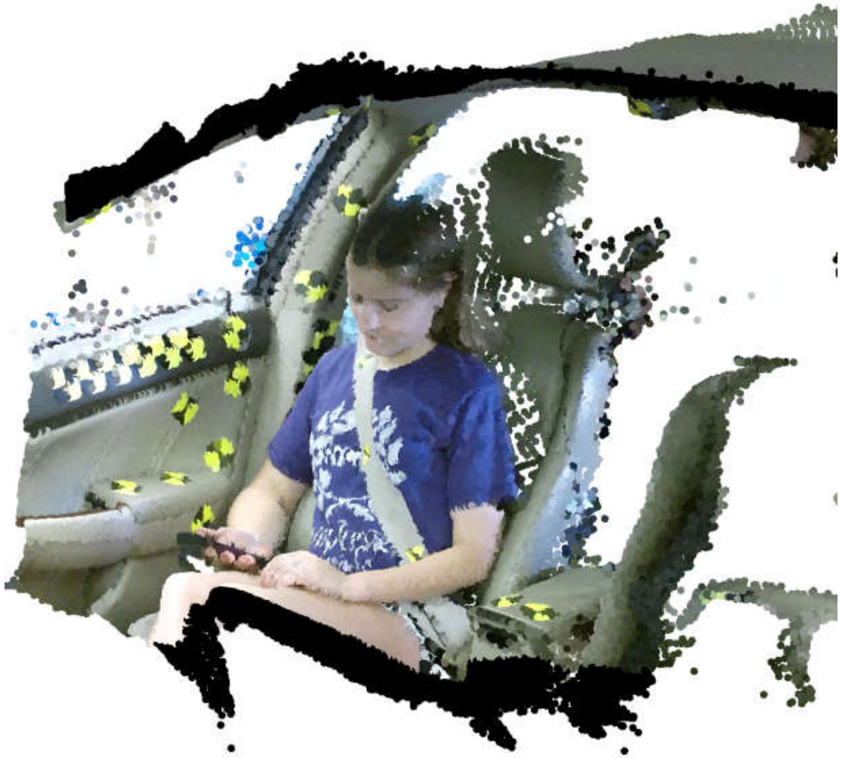
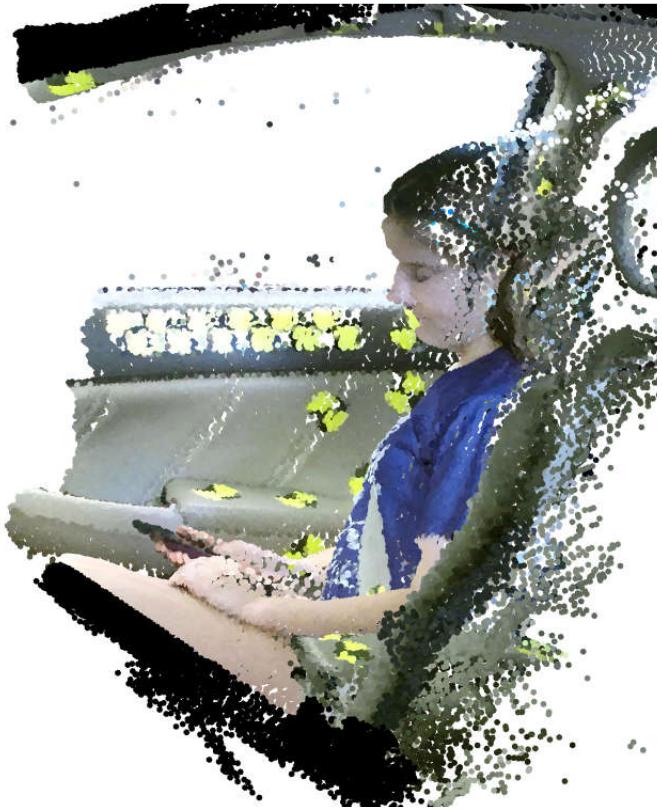
Child Postures

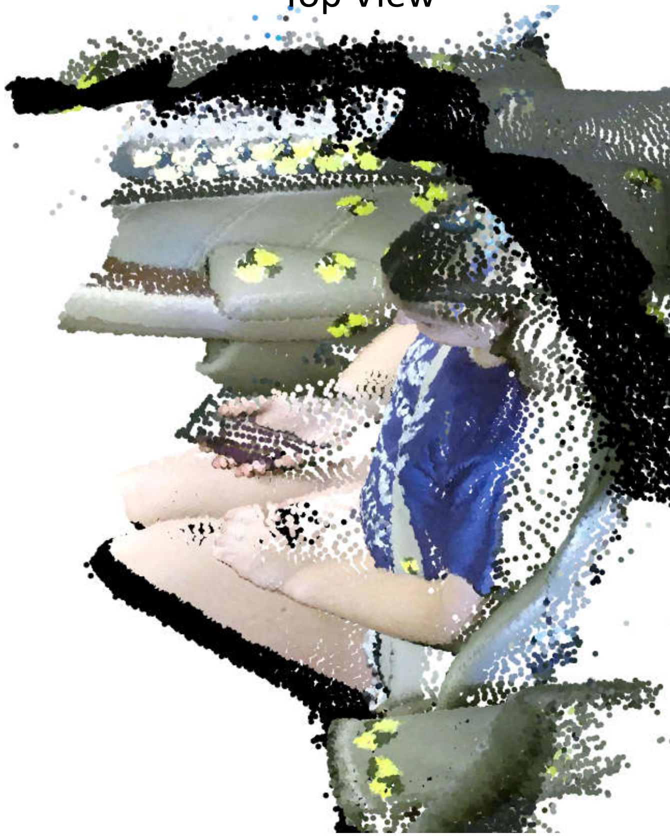
Sensor View



Side View



Top View



Sensor View

64k RGB-D data (3d with color)

Child Postures

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Child Postures

Frames from 30 Hz capture of RGB-D data (3d with color)
Background removed

What Can We Do?

How can we use this information?

- occupant characterization for restraint system optimization
- dynamic pre-crash restraint adjustment
- Provide feedback to occupants on posture and belt fit
- Modify vehicle dynamics

Acknowledgments

CChIPS | Center for Child Injury Prevention Studies

Sheila Ebert, Laura Malik, Monica Jones, K. Han Kim, Brian Eby, Kyle Boyle, Carl Miller

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Child Postures

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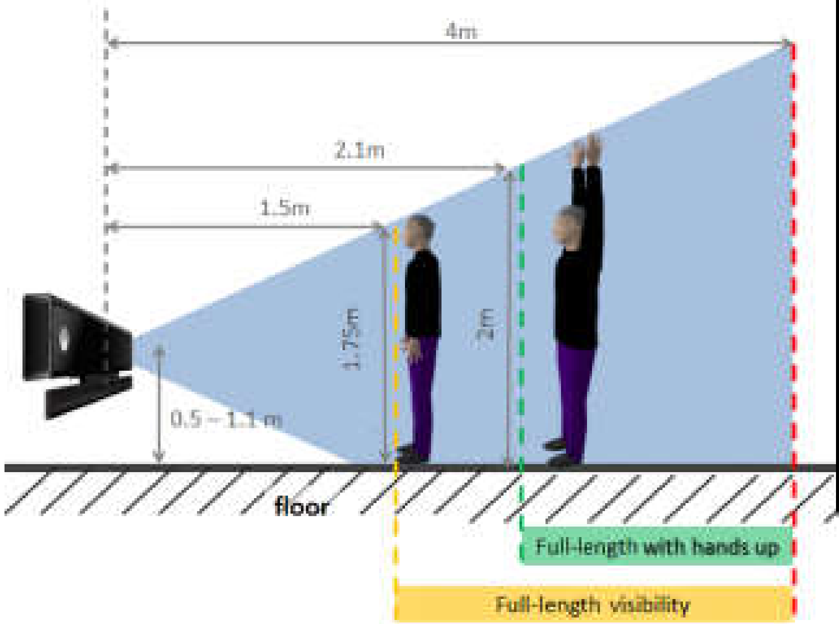
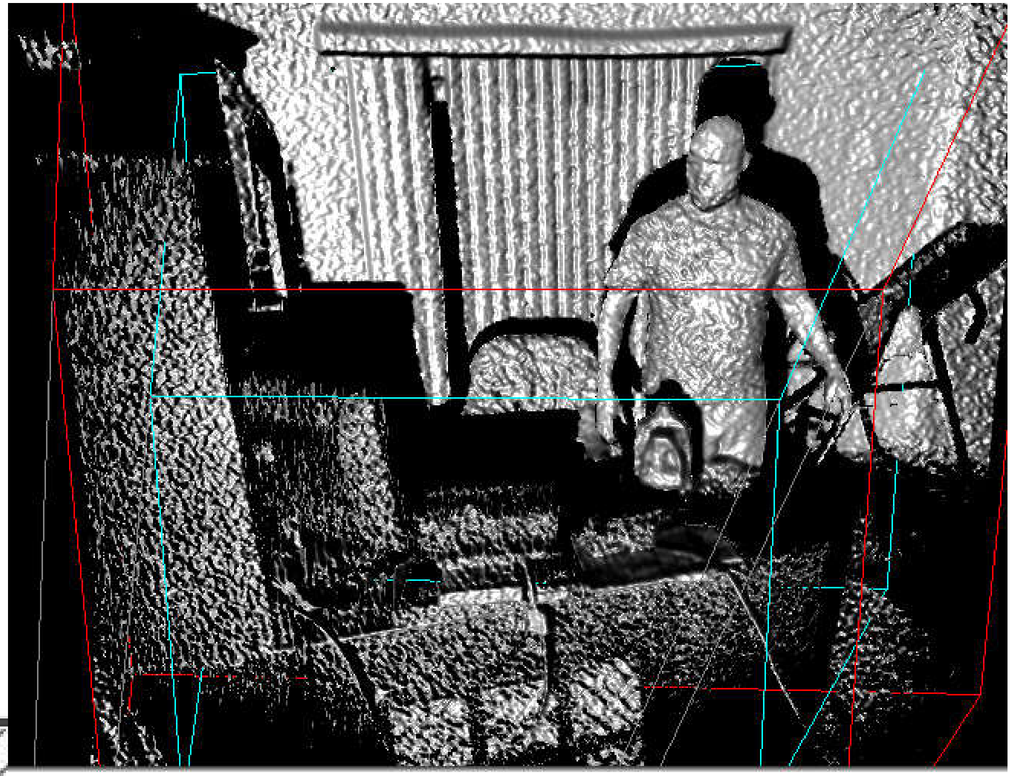
Kinect v2

- Specification of Kinect v2 sensor (vs. v1)
- Depth data resolution: 512 x 424 pixels (vs. 320 x 240)
- FOV: 70 x 60 degrees (vs. 58 x 46 deg.)
- Nominal tracking rate: 30 Hz (vs. 30 Hz)





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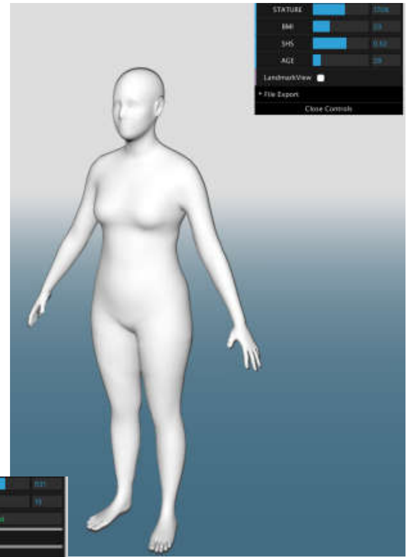
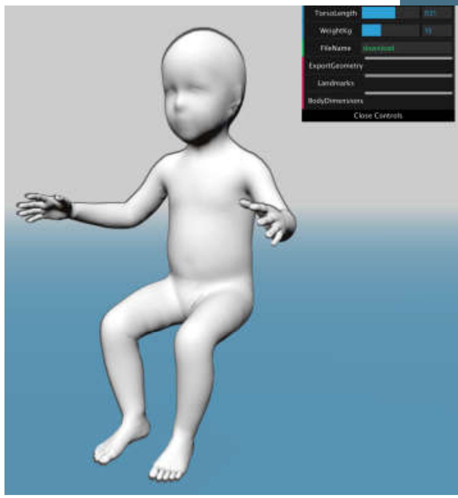
HumanShape.org





Portable Body Scanner using Kinect v2

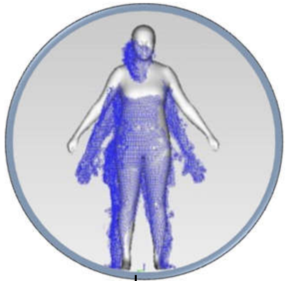
Four steps to generate a subject-specific avatar

1

Scanning subject
using a single Kinect sensor

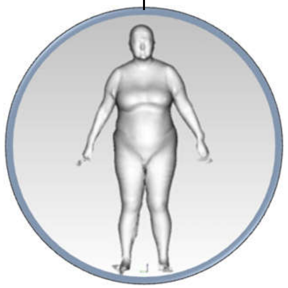
2

Merging scans
by minimizing sum of distances between scans



3

Aligning scan to model
using synthetic landmarks



4

Fitting to scan
in body shape space of model

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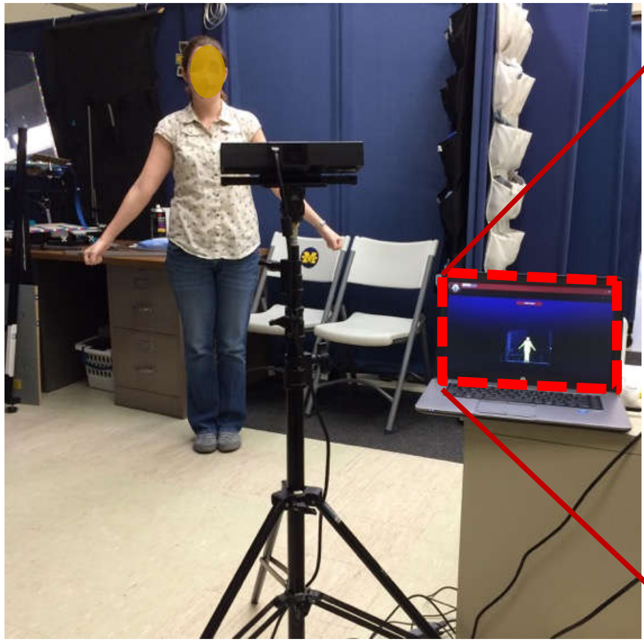
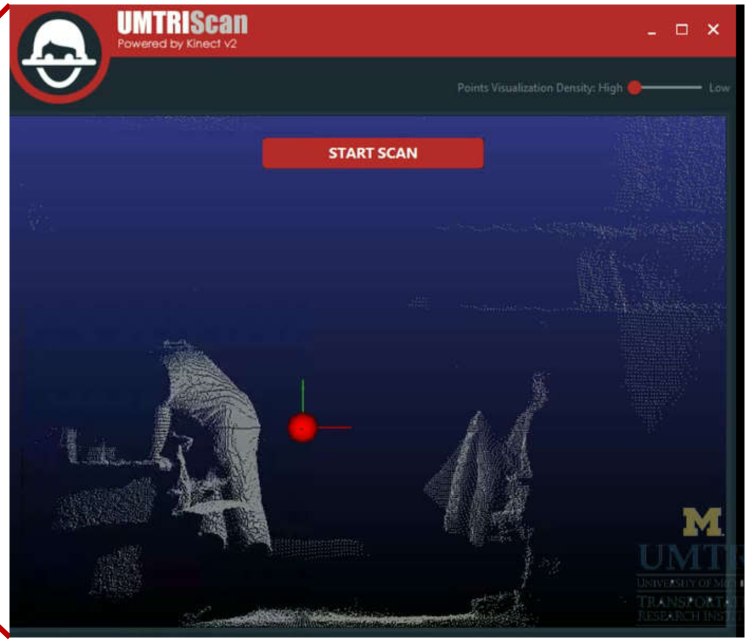


Hardware configuration for scanning



DEMO

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Application: Rapid Body Dimension Measurement

The model can be fitted to:

- 3D depth image
- 2D image
- Scan with clothing

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AgeAtTesting: 8.39
Weightkg: 30.22
Stature: 1307.86
ErectSittingHeight: 690.42
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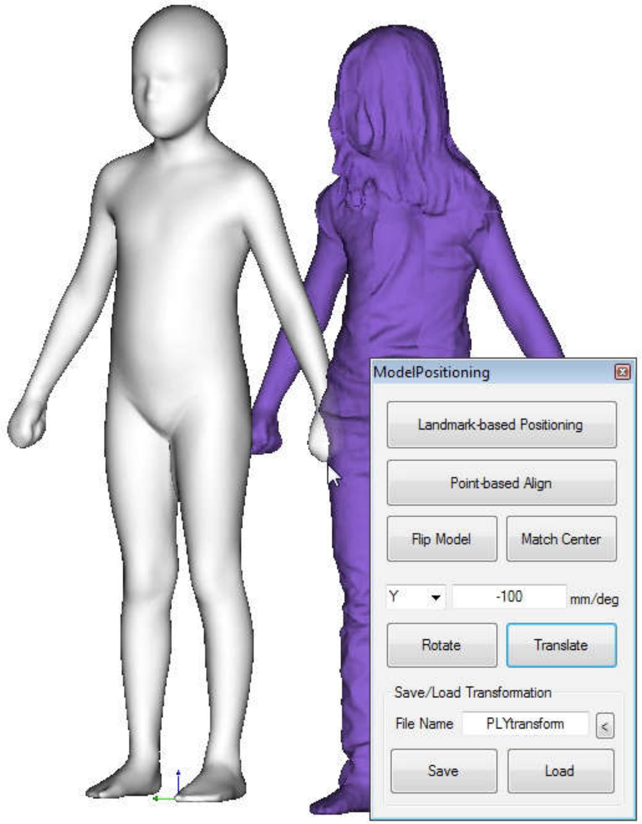

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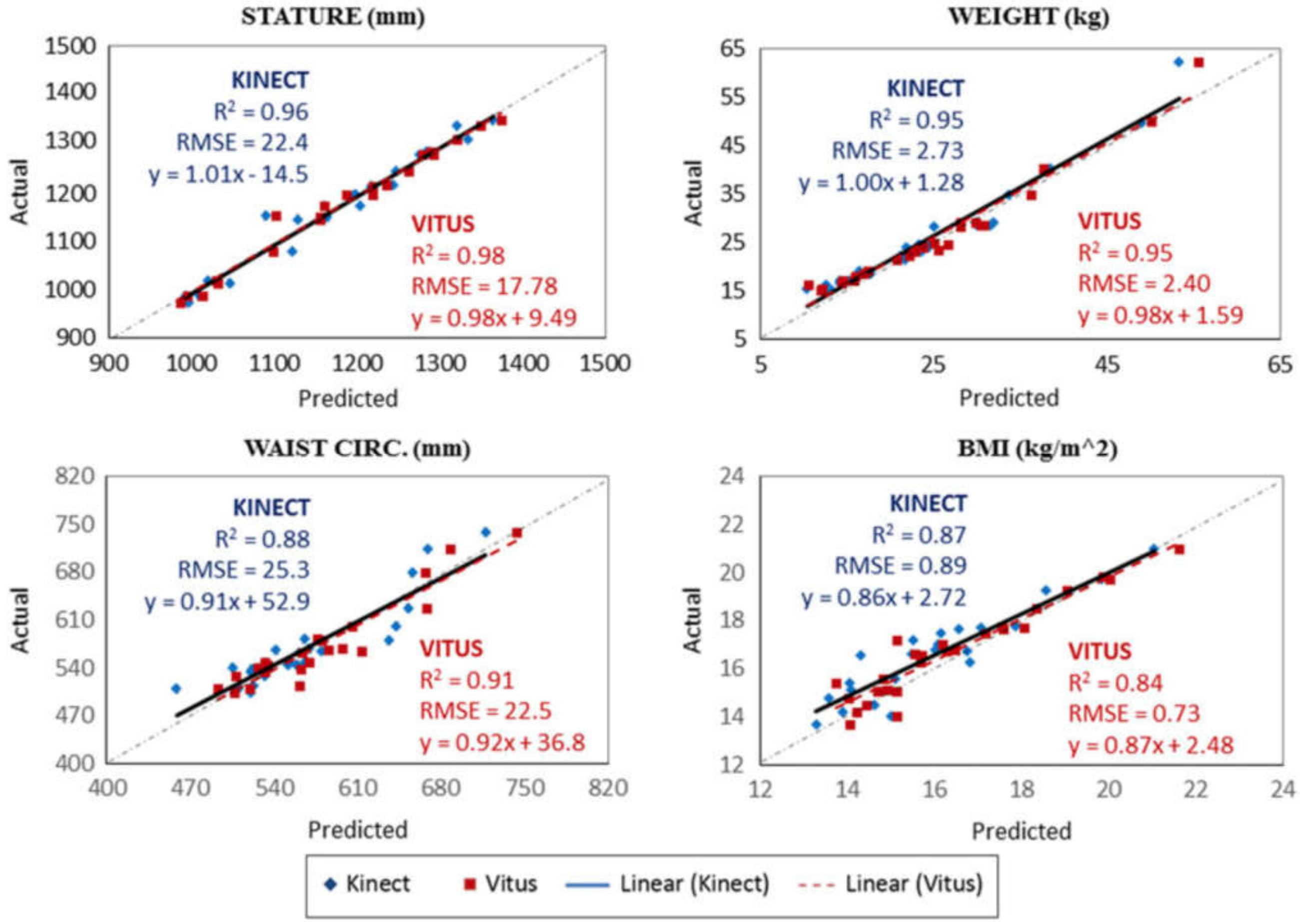
Body Dimension Estimates (minimally clad)



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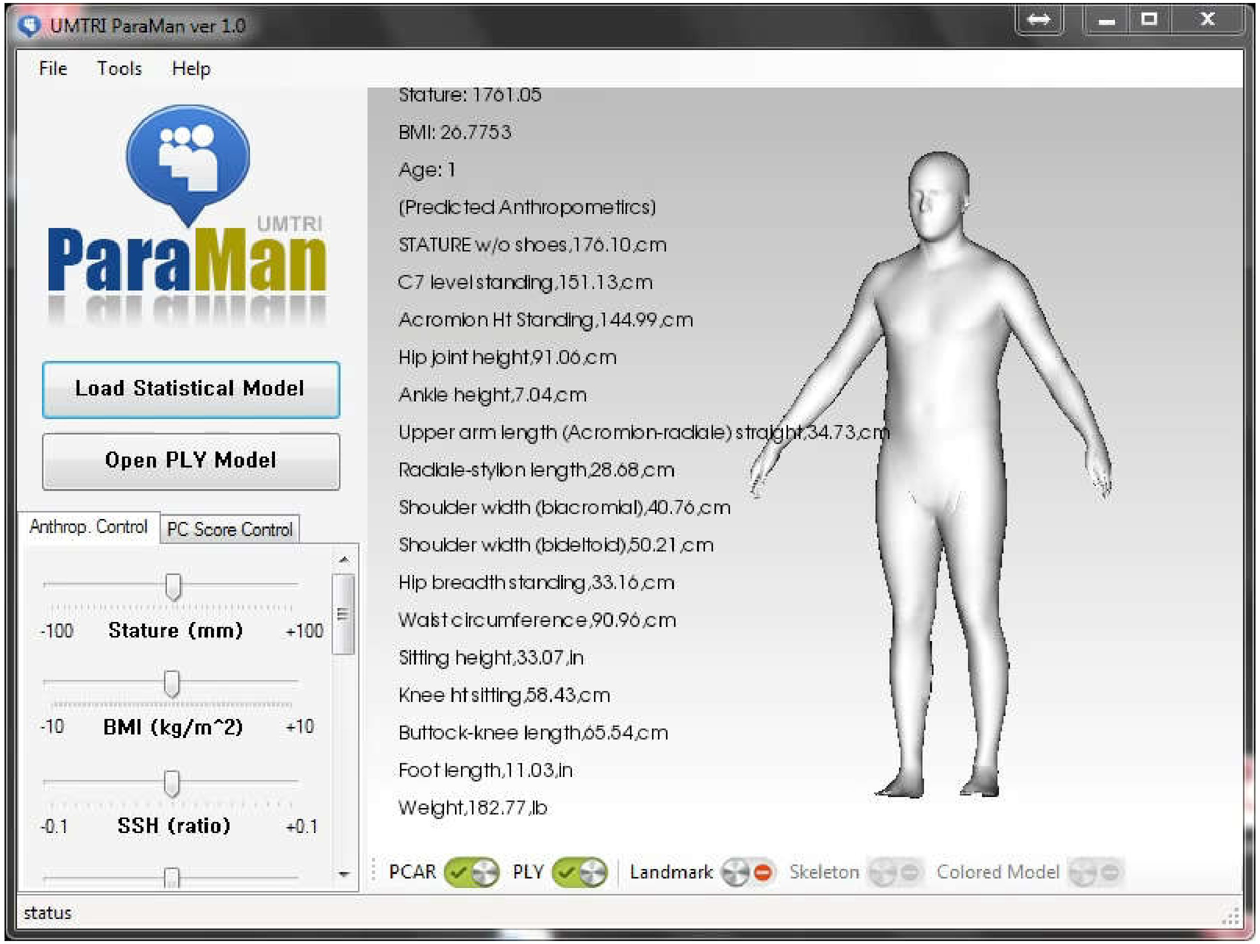
Fitting Demo



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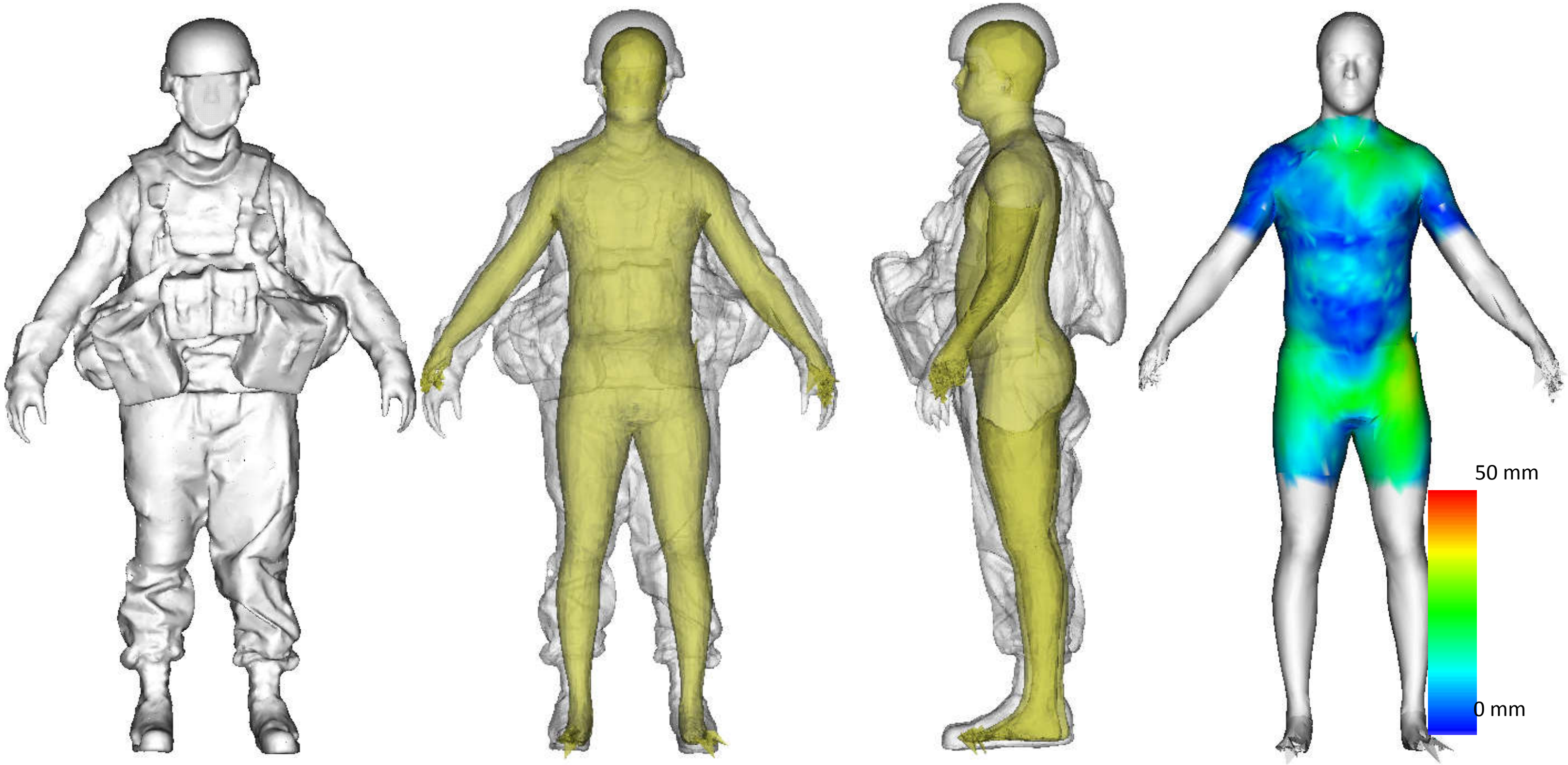
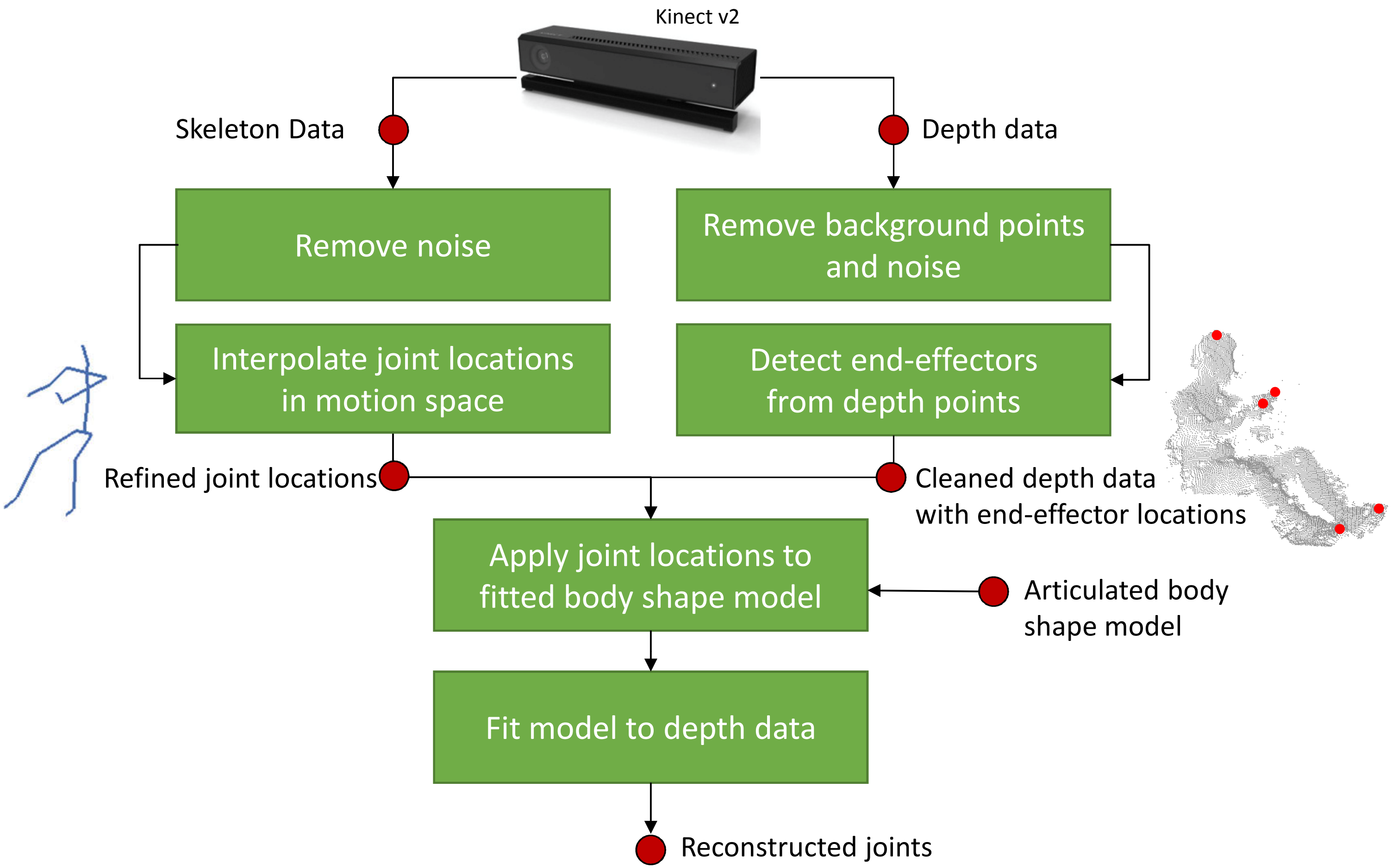
Adults



ENC level: mean 11.6 mm, 95th %tile 16.5 mm, RMSE 12.0 mm

Markerless-motion capture

Strategy for obtaining quality motion data



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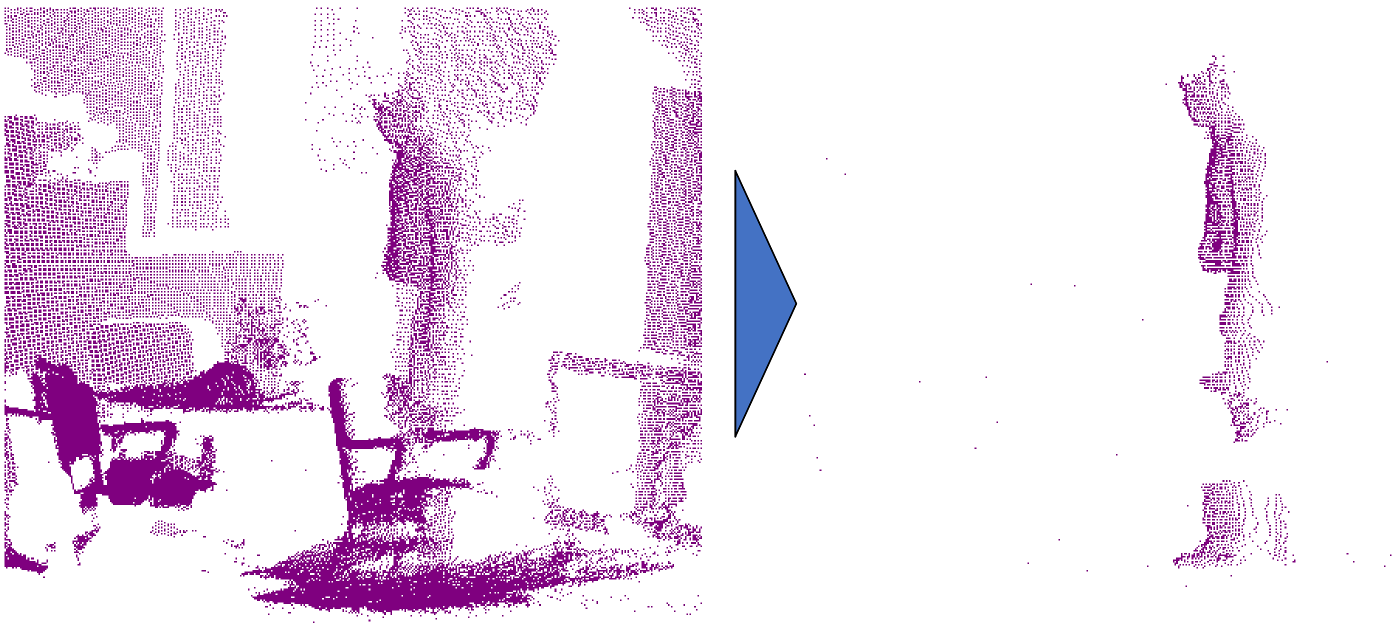
Background Subtraction

- Subtract background depth data to obtain depth related to the subject only
- Use multiple background images to reduce noise



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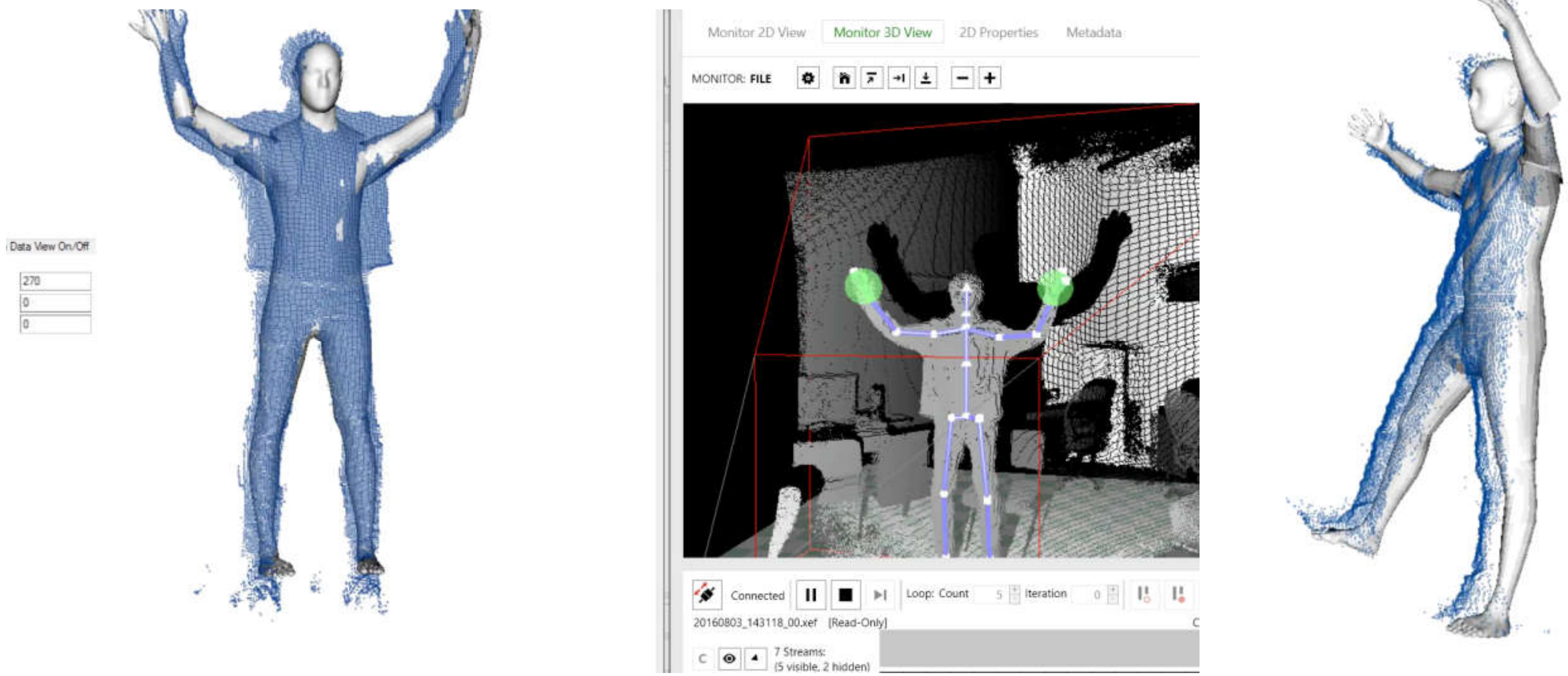
Kinect Joint Data

Reconstructed Kinect skeleton data are applied to the model



BioHuman Articulated Model and Kinect Joint Data

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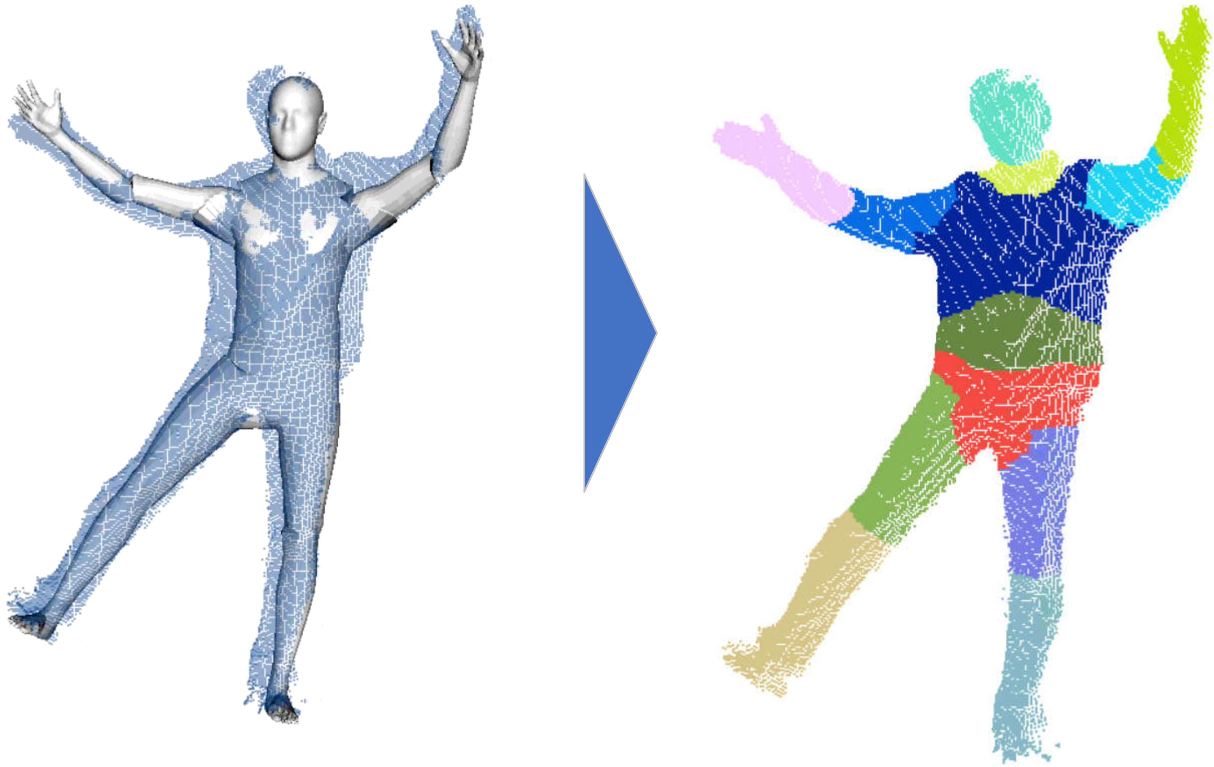
Model Fitting using Articulated ICP: Correspondences

K-d tree algorithm was used to rapidly find the correspondences of the depth points for each body segment



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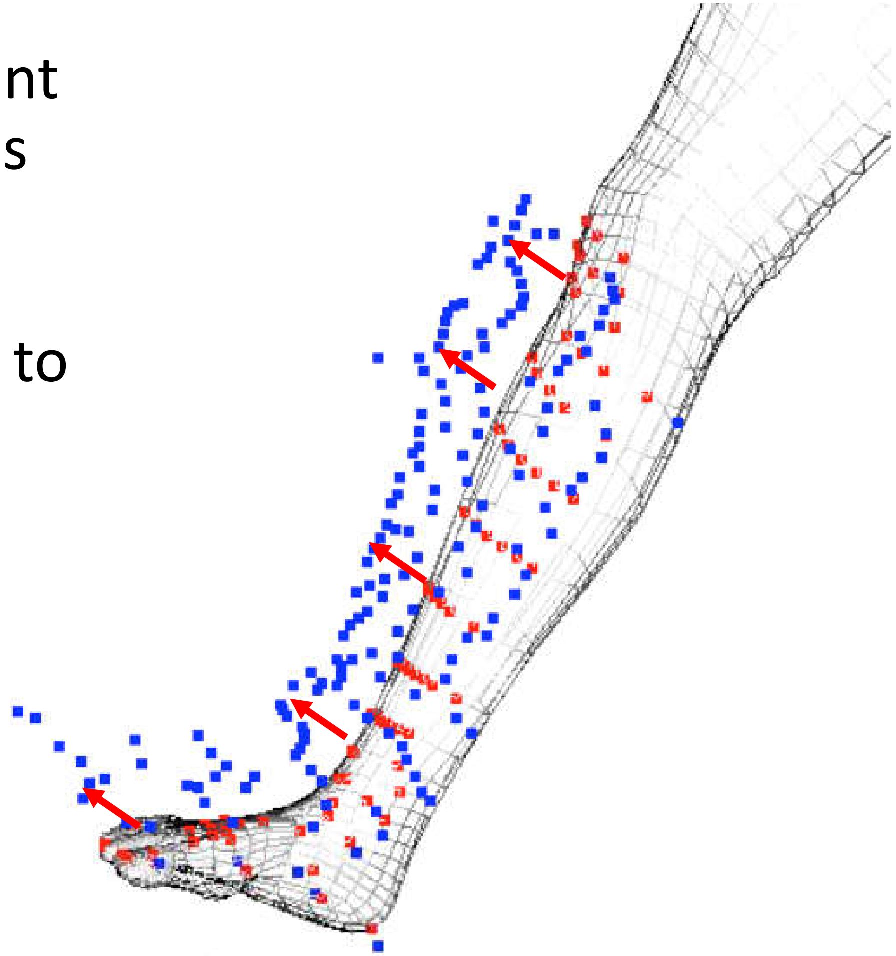
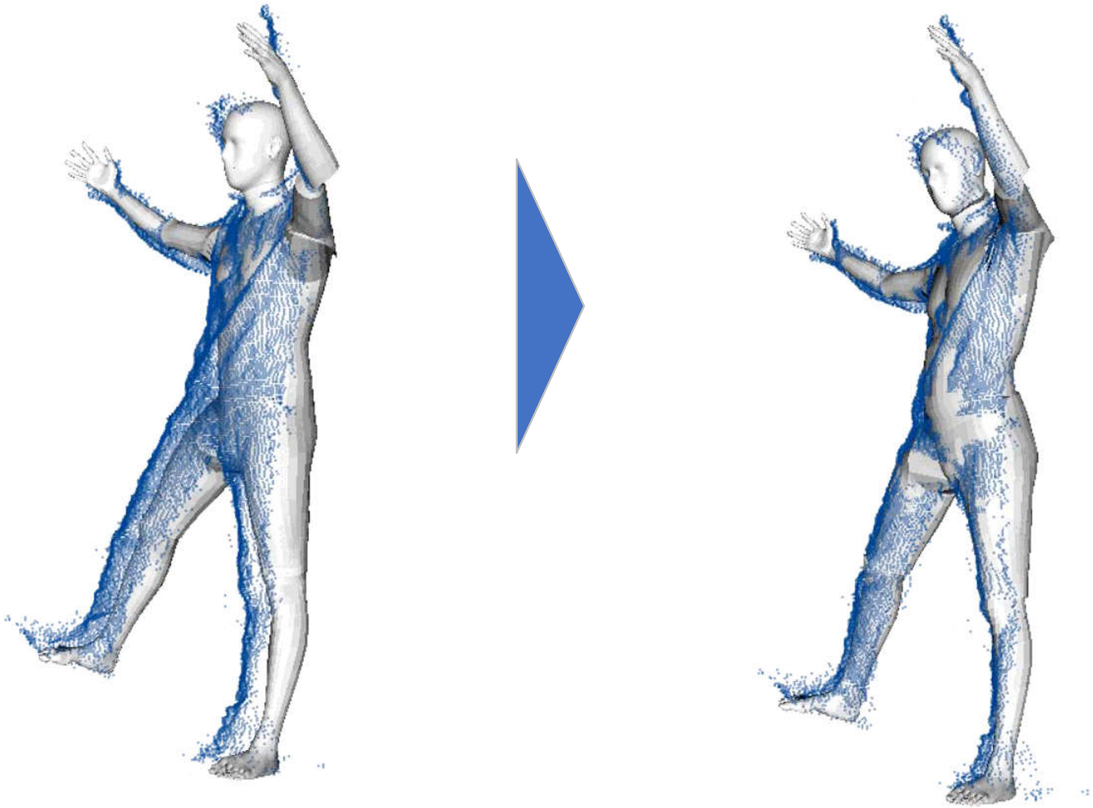
Model Fitting using Articulated ICP: ICP

Iterative closest point (ICP) algorithm finds the best transformation to align each segment to the corresponding depth point group

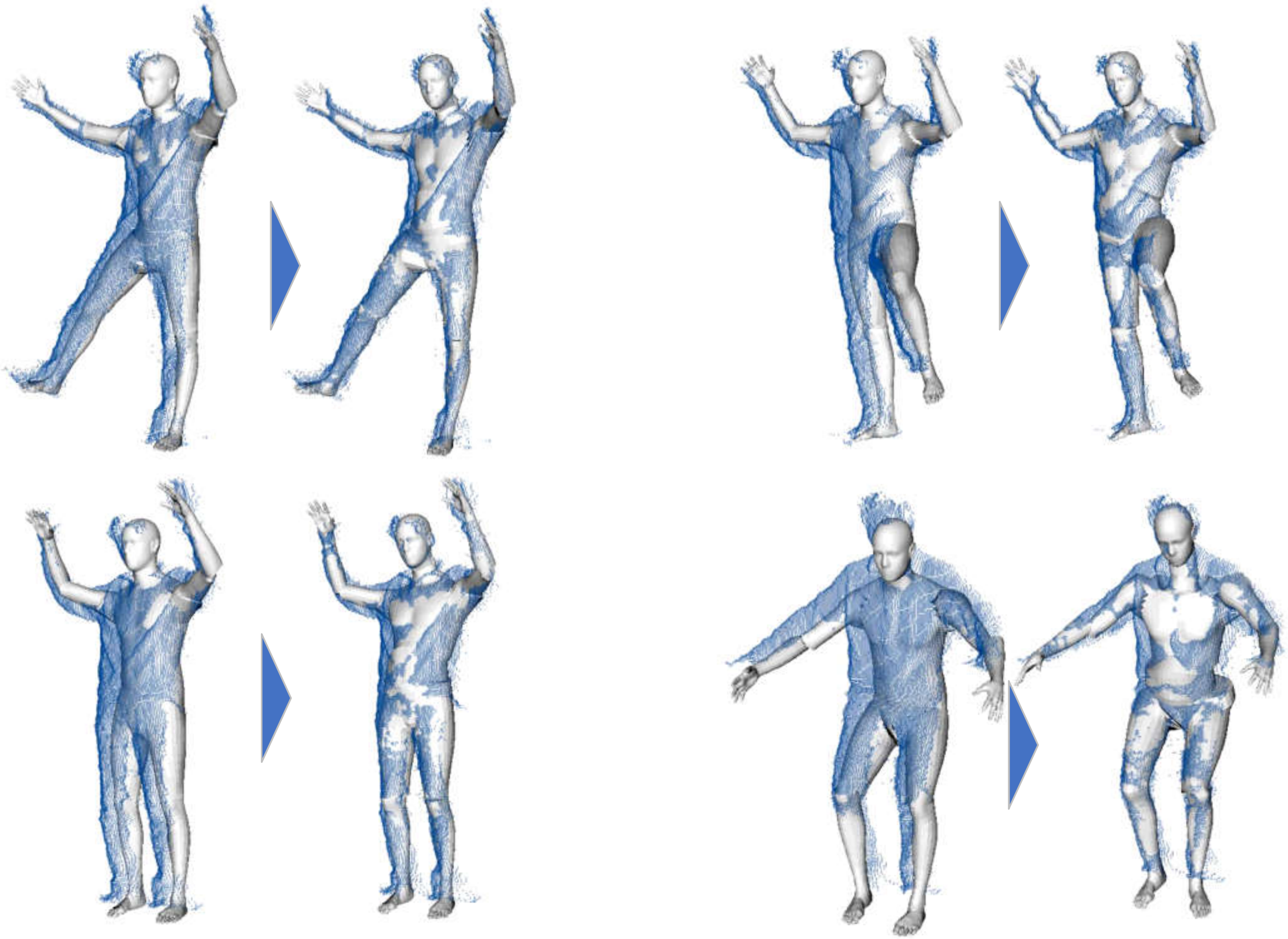


Model Fitting using Articulated ICP: Fine Adjustment

Apply fitted transformation matrices to all the body segments



Results



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