Reconstruction from multiple depth sensors

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INTRODUCTION

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- Complete human mesh models have many applications like gaming, film making, medical industry etc.
- Obtaining a complete model is difficult as scans are partial and noisy
- Goal - set up a system wherein a subject will be scanned using multiple depth sensors, and its corresponding body mesh will be generated robustly and correctly
- This task is known as registration, and several approaches have been tried in the past
- Here we present our literature survey, an algorithm that we plan to implement, and a tool we developed to visualize our setup

Literature survey

Variants of ICP

- Haehnel et al.(2003):
  - Transform scans into Markov random fields, where nearby measurements are linked by a (nonlinear) potential function
  - They solve this optimization problem by Taylor series expansion, followed by a coarse-to-fine hierarchical optimization technique for carrying out the optimization efficiently
- Mitra et al.(2004):
  - Improved upon ICP by developing an objective function that is a second order approximant to the squared distance between the model and the data
  - This incorporates higher order information about the surfaces represented by the point clouds, such as local curvatures
  - Their algorithm can’t simultaneously register multiple point clouds

Variants of ICP

- Brown and Rusinkiewicz(2004):
  - Present a non-rigid alignment algorithm for aligning high resolution range data in the presence of low-frequency deformations
  - Use thin-plate spline to represent the warp, based on feature correspondences computed using a hierarchical ICP method
- J.-D. et al.(2007):
  - Register facial point data obtained using CT scans of a patient, to provide medical assistance and preoperative training
  - Modified correspondence search in ICP by using ADAK-D tree, which uses AK-D tree twice in two different geometrical projection orders for determining the true nearest neighbor point
  - Improved the objective function of ICP, by modifying the soft-shape-context ICP algorithm proposed by Liu and Chen

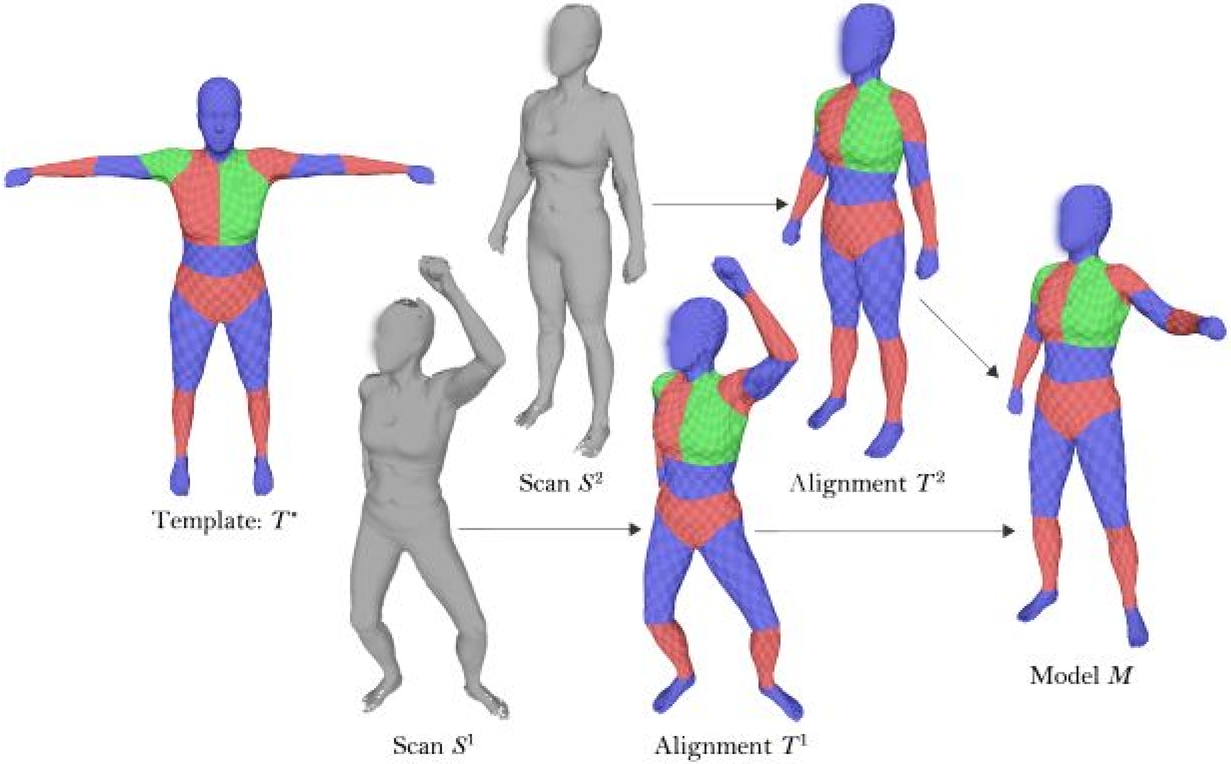
Variants of ICP

- Vetter et al.(2007):
    - Extend the ICP framework to nonrigid registration while retaining the convergence properties of the original algorithm
    - Present an algorithm using a locally affine regularisation which assigns an affine transformation to each vertex and minimises the difference in the transformation of neighboring vertices
- Bouaziz et al.(2013):
    - Avoids the difficulties, of sensitivity to outliers and missing data often observed in 3D scans, by formulating the registration optimization using sparsity inducing norms
    - They propose a sparse optimization problem that automatically learns the separation between data and outliers

Using database

- Anguelov et al.(2005):
  - Represents a human shape model that incorporates both articulated and non-rigid deformations
  - Learn a pose deformation model that derives the non-rigid surface deformation as a function of the pose of the articulated skeleton
  - Also learn a separate model of variation based on body shape
  - Can produce 3D surface models with realistic muscle deformation for different people in different poses
- Hirshberg et al.(2012):
  - This model serves to regularize how the template mesh can deform, to avoid impossible deformations of the template
  - They minimize a single objective function, to reliably obtain high quality registration of noisy, incomplete scans, while simultaneously learning a highly realistic articulated body model

Coregistration Overview



COREGISTRATION

Overview of the Algorithm

- The algorithm approaches modeling and registration simultaneously
- The model serves to regularize how the template mesh can be deformed, as registration tries to fit the mesh better
- Minimize a single objective function, to reliably obtain high quality registration of noisy, incomplete scans, while simultaneously learning a highly realistic articulated body model
- This model greatly improves robustness to noise and missing data.

Model: BlendSCAPE

- Human body shape deformation model - a modification over the SCAPE body model
- Parameters of the model:
  - Template mesh T^*
  - Relative joint angles θ in the articulated mesh model
  - Absolute rotation of each part $R(\theta)$
  - Person’s body shape deformation matrix D
  - Pose dependent shape changes $Q(\theta)$
  - Linear blend of rotations: $B(\theta)$

Model: Blendscape

- To pose and deform we unstitch the triangles
- Then apply our deformations: $T_f = B_f(\theta) D_f Q_f(\theta) T^*$
- Here B(θ) is defined by:

$$B_f(\theta) = \sum_i w_{fi} R^i$$

- Q(θ) is modeled by:

$$Q(\theta) = Q^0 + \sum_c \theta_c Q^c$$

Coregistration Optimization Problem

- Fitting deformed template to scan term:

$$E_S(T;S) = \frac{1}{a_S} \int_{x_s \epsilon S} \rho\left(min_{x_t \epsilon T} ||x_s - x_t|| \right)$$

- Penalizing deviation from learned model:

$$E_C(T, \theta, D, Q) = \sum_f a_f \left|\left| T_f - B_f(\theta) D_f Q_f(\theta) T_f^* \right|\right|_F^2$$

- Regularizing model training:

$$E_D(D) = \sum_{adjacent\ faces\ i,j} a_{i,j} \frac{||D_i - D_j||_F^2}{h_{ij}^2}$$

$$E_Q(Q) = \sum_{faces\ f} a_{i,j} \left(||Q_f^0 - I||_F^2 + \sum_c ||Q_f^c||_F^2 \right)$$

Coregistration Optimization Problem

- Final optimization problem:

$$\min_{T^k,\theta^k,D^P,Q} \sum_{scans\ k} [E_S(T^k;S^k) + \lambda_C(E_C(T^k,\theta^k,D^P,Q))] + \lambda_C[\lambda_D \sum_P E_D(D_P) + \lambda_Q(E_Q(Q)]$$

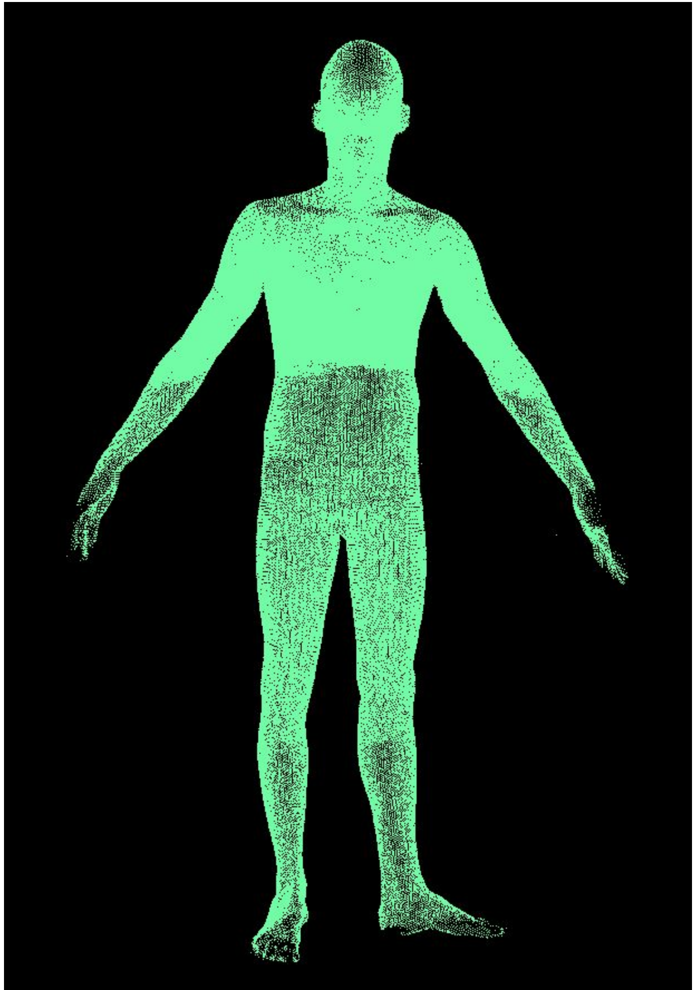
- Here, p indexes people, k indexes scans, and p_k identifies the person in each scan
- λ_C controls how much the alignments can deviate from the model

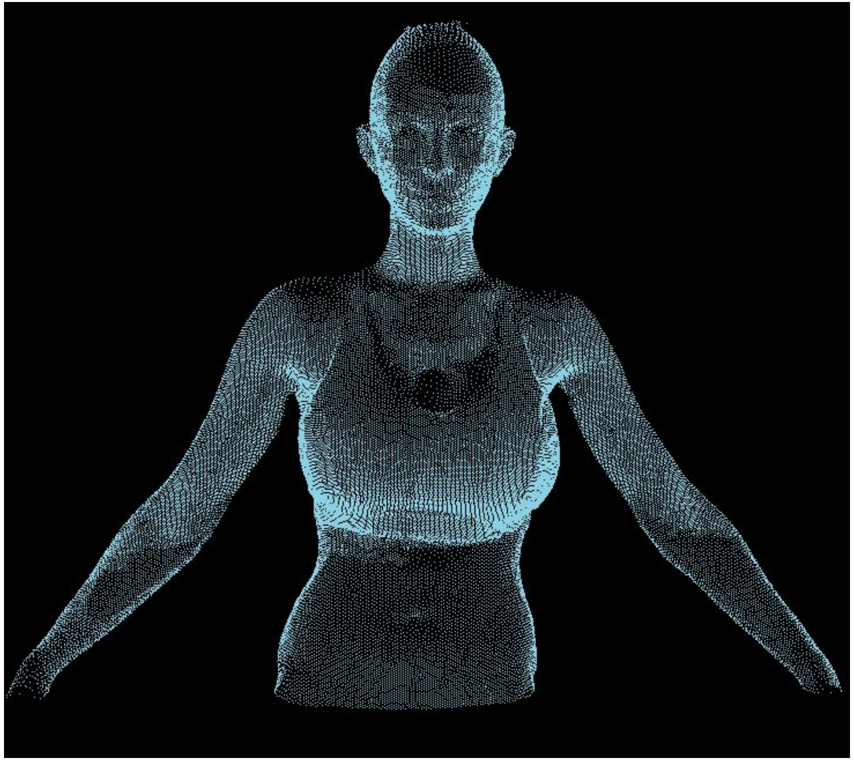
Optimization

- The paper suggests the following optimization techniques
- Decouple the scans by fixing D^p and Q, and minimize for each scan: $\min_{T^k,\theta^k} E_S(T^k; S^k) + \lambda_C(E_C(T^k, \theta^k, D^{p_q}, Q))$
- This is a non linear least squares data fitting problem
- Now fix T^k and Q(), and minimize with respect to each person's D^p - linear least squares problem for each person p
- Similarly, fix T^k and D^p, and minimize with respect to $Q_f()$ - linear least squares problem for each triangle f

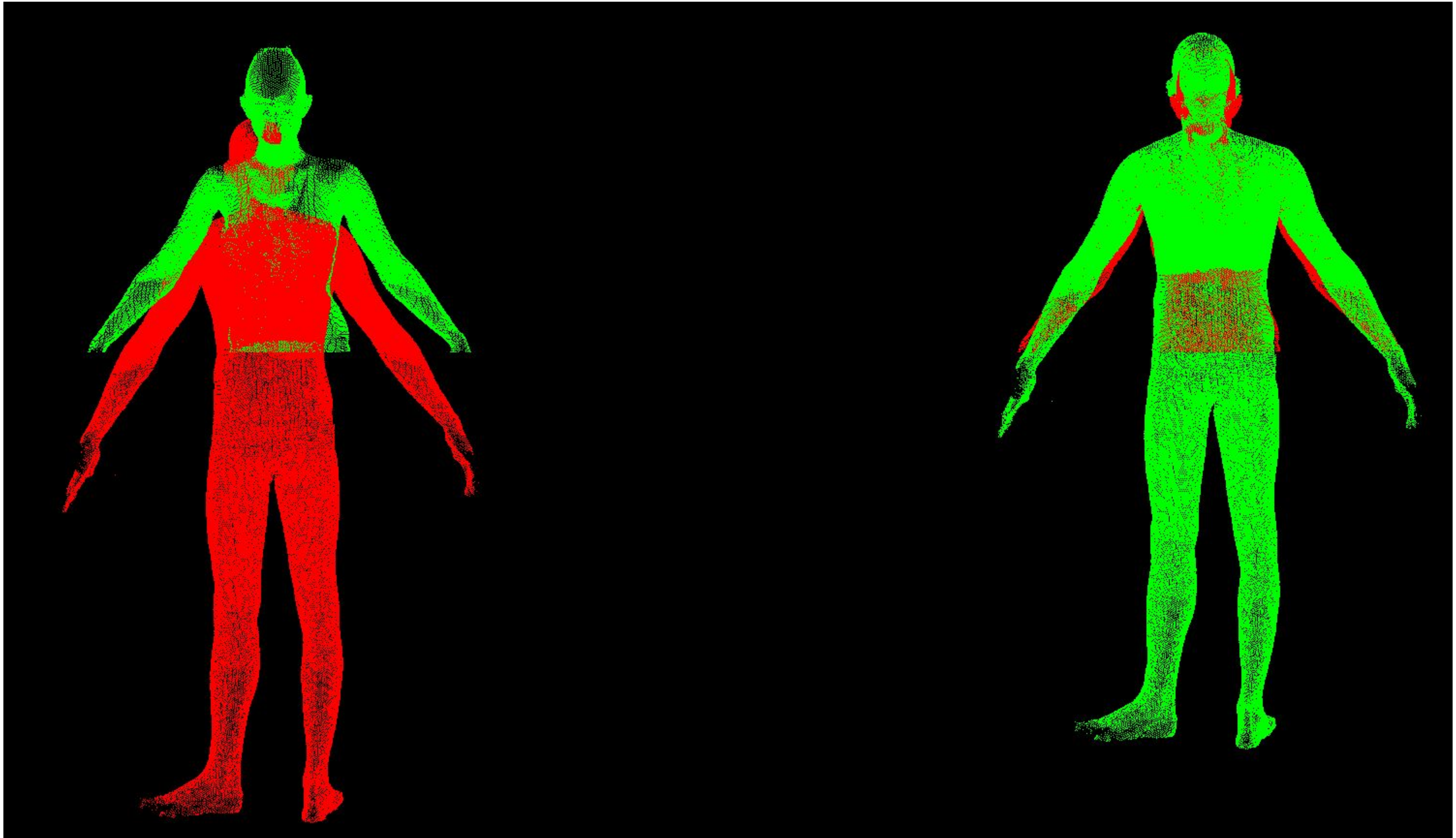
Our work

PCL ICP Alignment

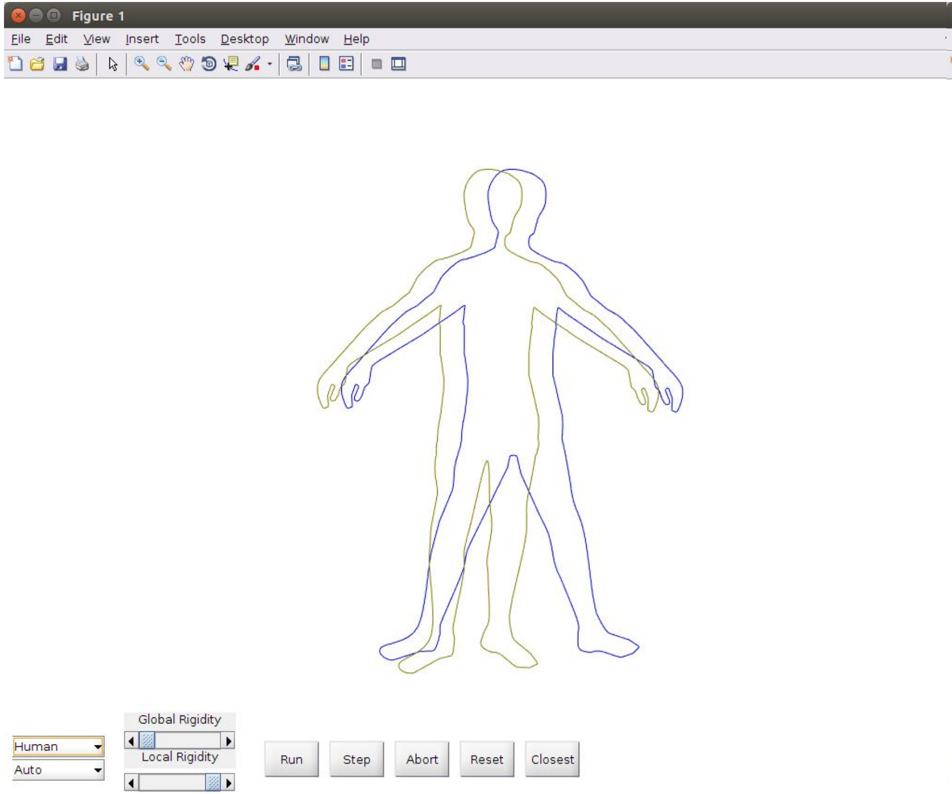


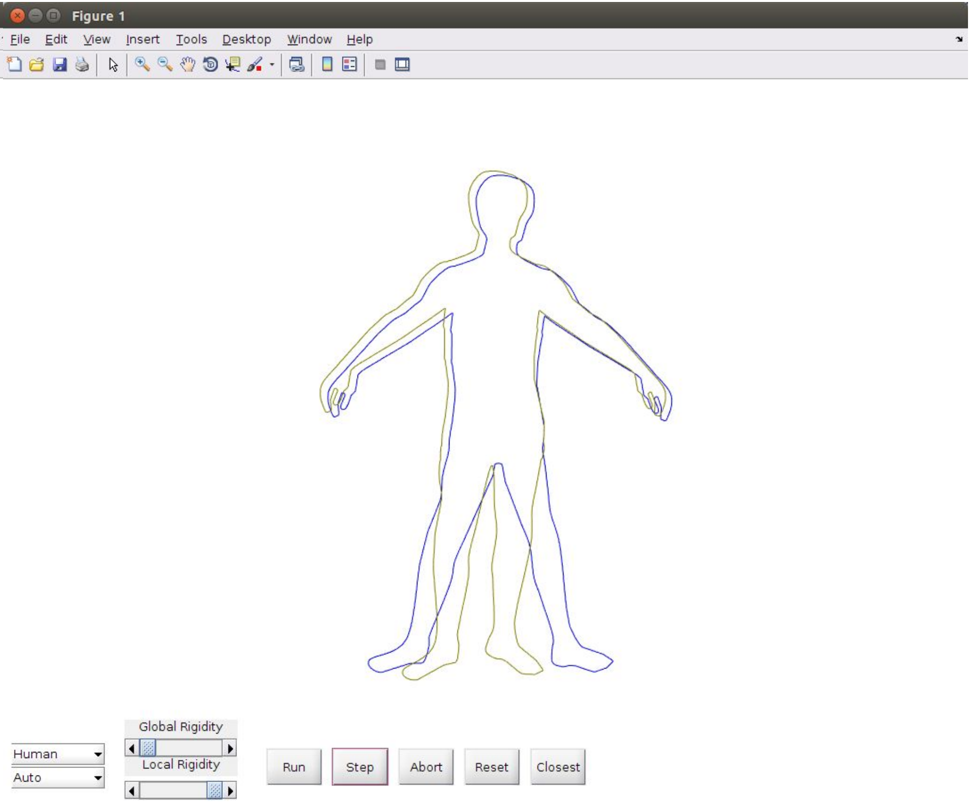


PCL ICP Alignment



Registration by Pauly et al.





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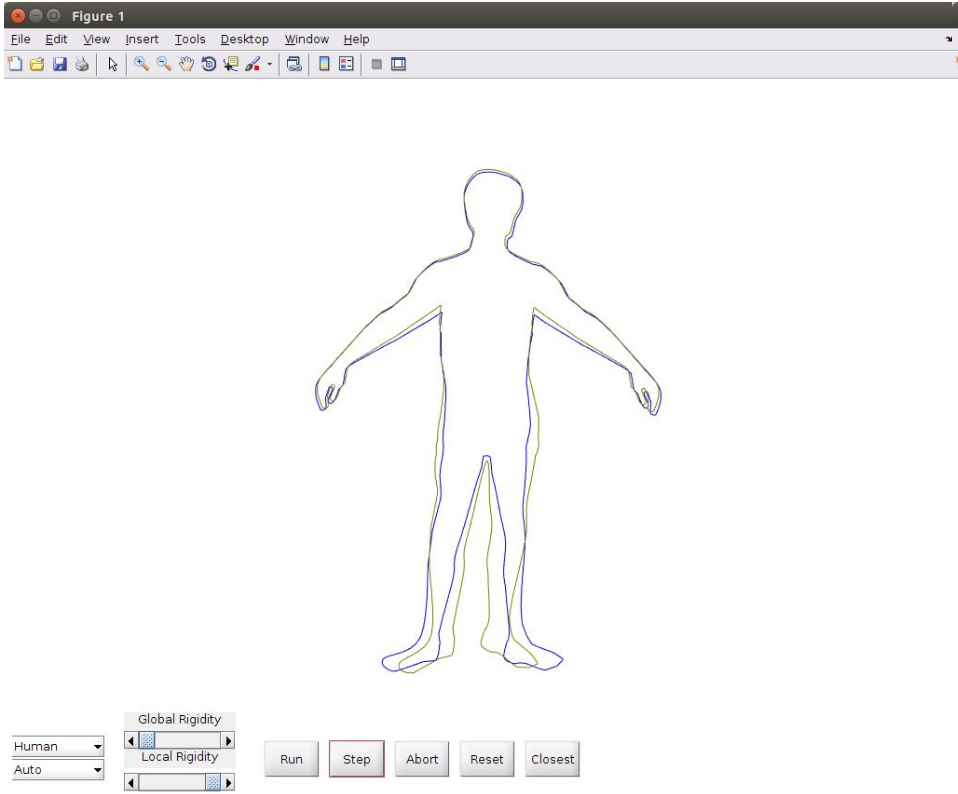
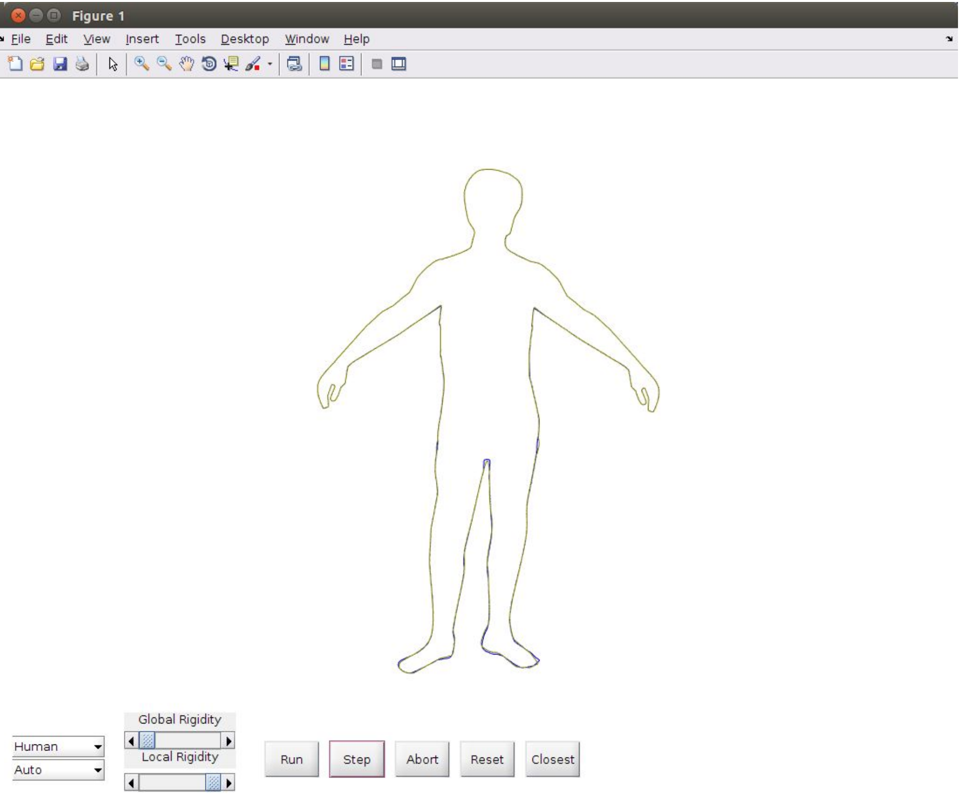
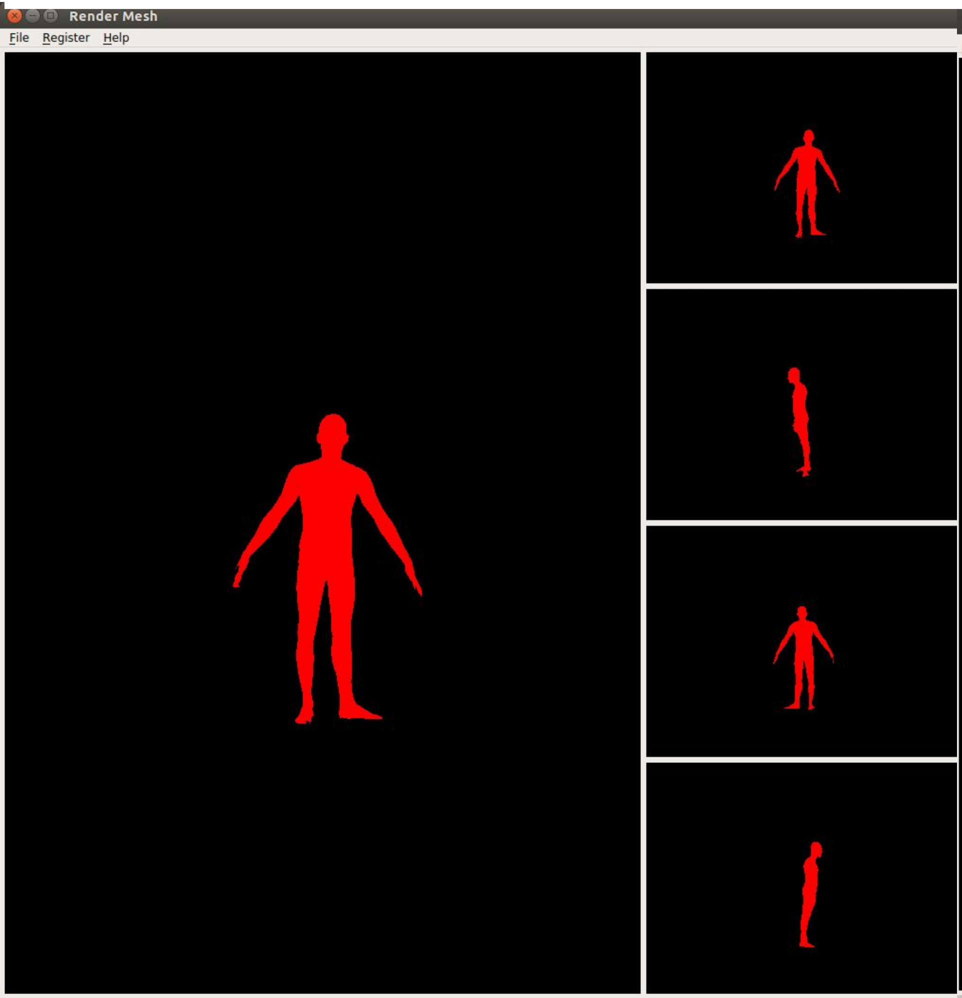
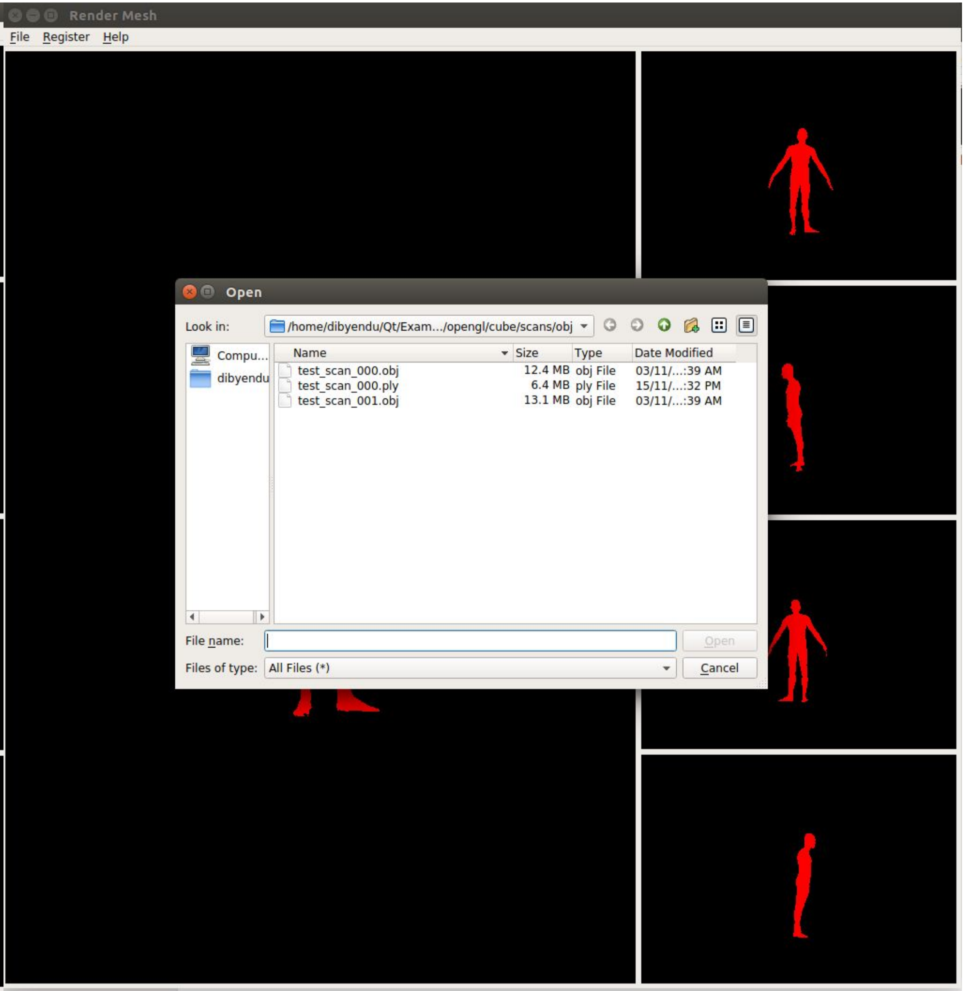


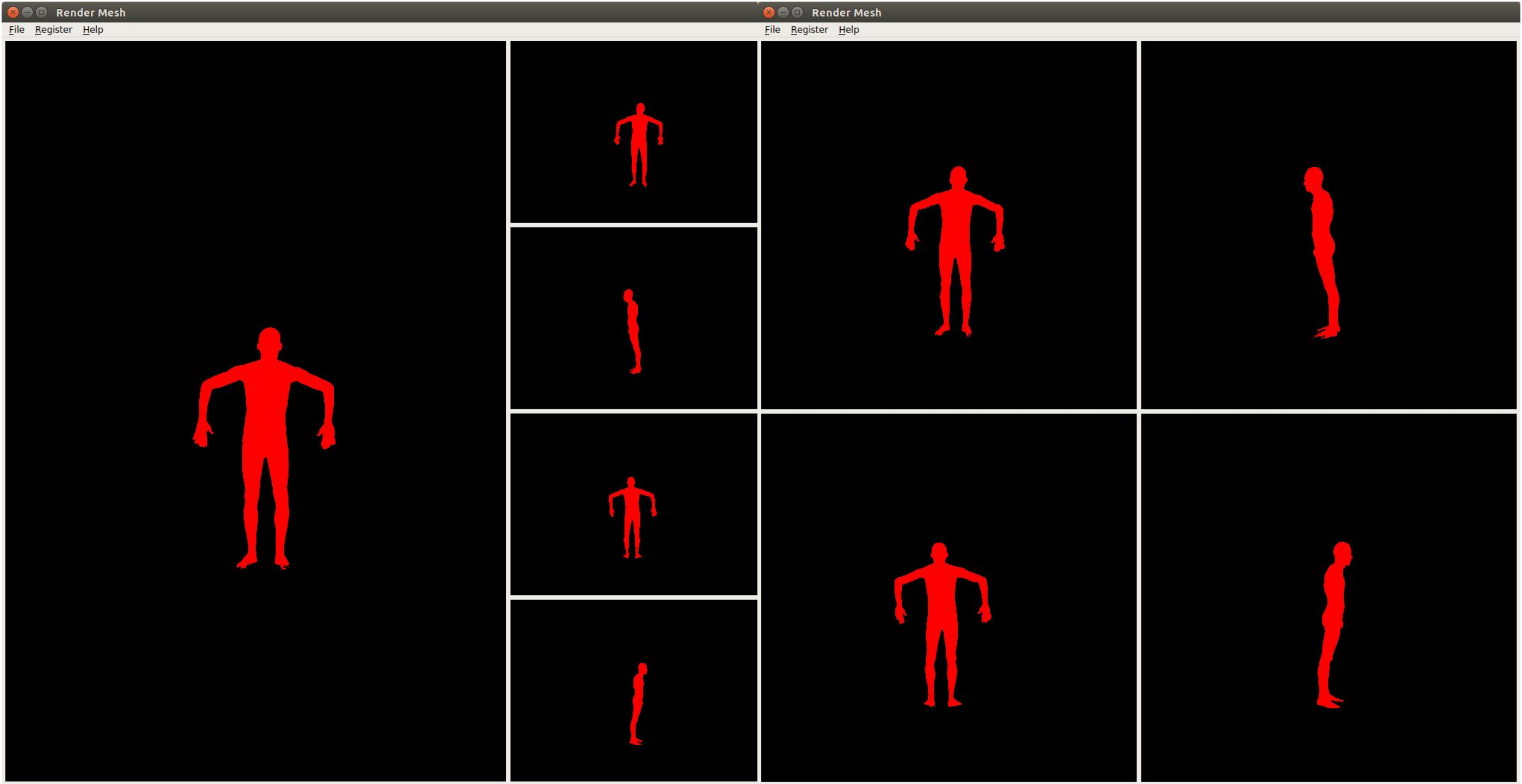


Visualization tool





Visualization tool



Future work

Future work

- Implement the coregistration algorithm and register the point clouds generated by our tool
- Generalize the algorithm such that it works for any scan
- Set up the room in ViGIL lab with 4 Kinects with proper fixed stands
- Take partial scans from the Kinect device and feed them as inputs for the registration algorithm using our tool
- Main aim will be to increase the robustness

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Thank you