Reconstruction from multiple depth sensors

By Kunal Agrawal & Dibyendu Mondal
Guides: Parag Chaudhuri & Siddhartha Chaudhuri
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 $\theta$ 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: \( T_f = B_f(\theta)D_fQ_f(\theta)T^* \)
- Here \( B(\theta) \) is defined by:
  \[
  B_f(\theta) = \sum_i w_{f_i} R^i
  \]
- \( Q(\theta) \) is modeled by:
  \[
  Q(\theta) = Q^0 + \sum_c \theta_c Q^c
  \]
**Coregistration Optimization Problem**

- **Fitting deformed template to scan term:**
  \[
  E_S(T; S) = \frac{1}{a_S} \int_{x \in S} \rho\left(\min_{x_t \in T} \|x - x_t\|\right)
  \]

- **Penalizing deviation from learned model:**
  \[
  E_C(T, \theta, D, Q) = \sum_f a_f \left\| T_f - B_f(\theta)D_fQ_f(\theta)T_f^* \right\|_F^2
  \]

- **Regularizing model training:**
  \[
  E_D(D) = \sum_{\text{adjacent faces } i,j} a_{i,j} \frac{||D_i - D_j||_F^2}{b_{ij}^2}
  \]
  \[
  E_Q(Q) = \sum_{\text{faces } f} a_{i,j} \left( ||Q_f^0 - I||_F^2 + \sum_c ||Q_f^c||_F^2 \right)
  \]
Coregistration Optimization Problem

- Final optimization problem:
  \[
  \min_{T_k, \theta_k, D_P, Q} \sum_{scans \ k} [E_S(T^k; S^k) + \lambda_C(E_C(T^k, \theta^k, D^P, Q))] + \lambda_D \sum_P E_D(D_P) + \lambda_Q(E_Q(Q))
  \]

- Here, \( p \) indexes people, \( k \) indexes scans, and \( p_k \) identifies the person in each scan.
- \( \lambda_C \) 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: \[ \min_{T^k, \theta^k} E_S(T^k; S^k) + \lambda C(E_C(T^k, \theta^k, D^{pq}, Q)) \]
- 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
Registration by Pauly et al.
Registration by Pauly et al.
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
REFERENCES

References
