Generating a 3D Hand Model from Frontal Color and Range Scans

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1. Introduction

o An accurate 3D hand model is important for
- Real-time tracking
- Pose estimation
- Human-computer interaction

o Generative and discriminative hand pose estimation methods require a realistic hand model for their application in real-world scenarios.

o Existing 3D reconstruction methods are limited by noise, form factor, and the requirement to capture multiple images for producing a complete hand model [1].

o A modelling method is required for generating realistic watertight hand models that can encode user-specific variations in hand geometry.

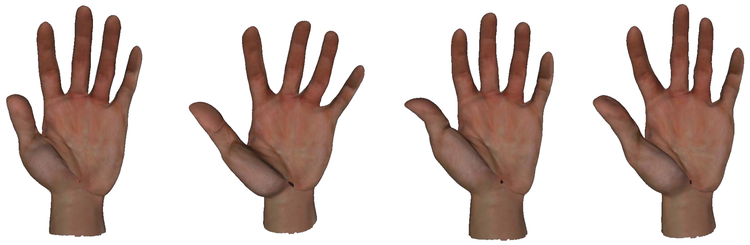

Figure 1: Example 3D hand models generated by the proposed method.

2. Contributions

o The method produces a full watertight 3D hand model using only a frontal color and range image.

o A Naive Bayes approach to extract finger contours using gradient and spatial priors is introduced.

o The output synthetic hand model captures the details in shape, size and pose of a real human hand.

o The method implicitly infers the back side of the hand by applying shape and size variations from the frontal scan.

3. Methodology

o The proposed method extracts joint locations from the color image using a fingertip and interfinger region detector (Fig. 3) with the following Naive Bayes probabilistic model (Fig. 4).

$$p(c_i \mid h) \propto p(h \mid c_i)\, p(c_i)\,, \qquad c_i{}^{*} = \arg\max_{c_i} p(c_i \mid h)\,.$$

o **Rigid registration** is performed using direct correspondence between the extracted joint locations and a synthetic hand model (Fig. 5).

o **Non-rigid registration** is achieved by a thin-plate-spline deformation of the registered synthetic model [2].

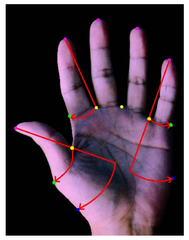

Figure 3: Fingertip and valley points extraction.

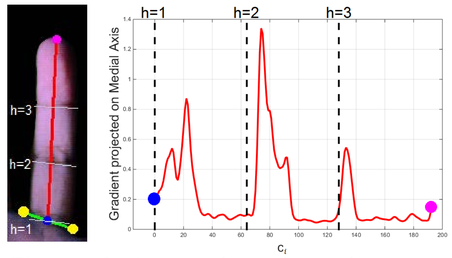

Figure 4: Crease detection using Naïve Bayes probabilistic model.

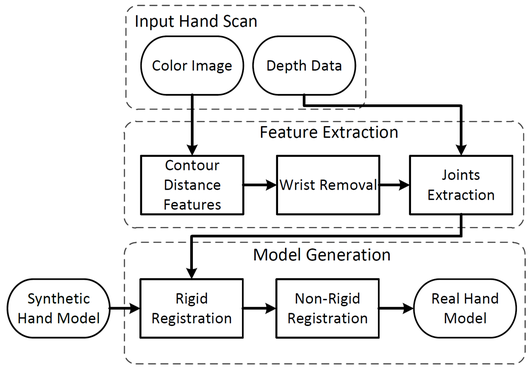

Figure 2:Flowchart of the proposed method.

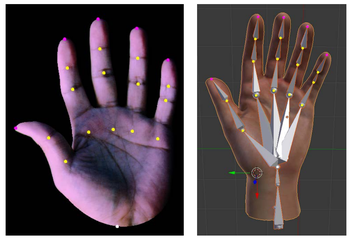

Figure 5:Correspondence between the joints extracted from real hand data and synthetic hand model.

4. Results

o Experimental results demonstrate the promise of the method to produce detailed and realistic 3D hand models that maintain similar geometric properties as of the range scan [3], but additionally includes the back side of the hand.

Table 1: Euclidean distance error between input data and predicted model. All measurements are in millimetres (mm).

Input data	Min error	Max error	Average error
1	0.04	25.02	5.58
2	0.10	10.54	2.74
3	0.03	20.47	2.65
4	0.07	12.20	3.43
5	0.03	16.06	3.69
6	0.08	15.06	2.58
7	0.09	19.29	4.85
Total Average	**0.06**	**16.95**	**3.65**
GT Model (Fig. 7)	0.12	13.91	2.51

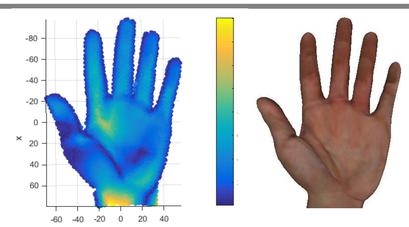

Figure 6: (left) Error in the hand model generation visualized using Euclidean distance for model 5 in Table 1 and (right) the generated model.

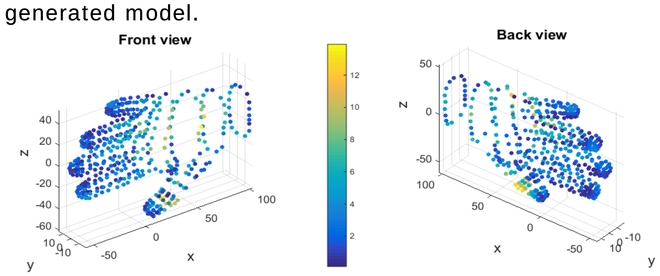

Figure 7: Euclidean distance error using a ground-truth synthetic model with both the front and back side.

[1] Izadi, Shahram, et al. "KinectFusion: real-time 3D reconstruction and interaction using a moving depth camera." Proceedings of the 24th annual ACM symposium on User interface software and technology (2011).
[2] Bookstein, Fred L. "Principal warps: Thin-plate splines and the decomposition of deformations." IEEE Transactions on Pattern Analysis & Machine Intelligence, 6 (1989): 567-585.
[3] Kanhangad, Vivek, Ajay Kumar, and David Zhang. "A unified framework for contactless hand verification." IEEE Transactions on Information Forensics and Security, 6.3 (2011): 1014-1027.