Real-time Estimation of Human-Cloth Relationship using Depth Sensor for Robotic Clothing Assistance

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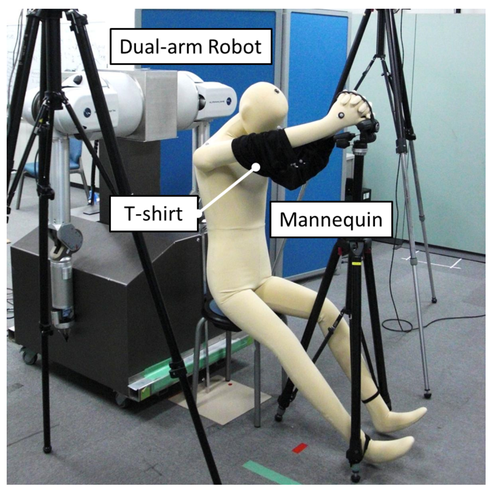
Introduction

Objective: Robotic Clothing Assistance is a challenging problem involving *interaction with Human and Clothing material*. In this study, we propose a method for the realtime estimation of the Human-Cloth topological relationship using a depth sensor.

Tamei et. al.[1] developed clothing assistance robot to perform T-shirt clothing task:

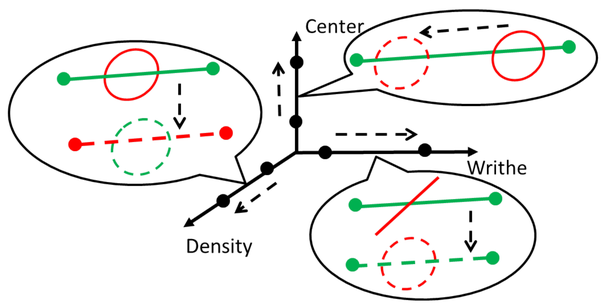
- **Reinforcement Learning** scheme used to acquire motor skills for cloth handling.
- **Low dimensional represetations** of state and policy used to ensure fast learning time.

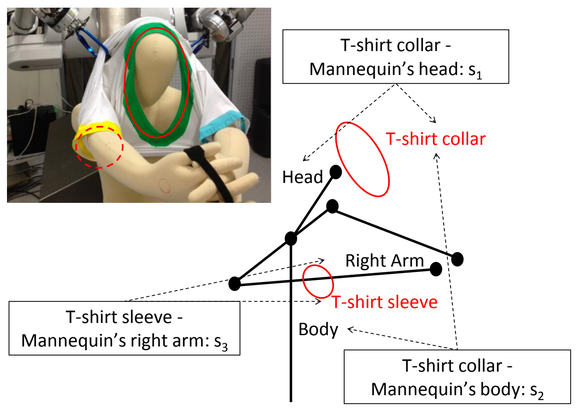


Problem Decription

Topology Coordinates[2] represents interaction between two curves using low dimensional variables:

- **Writhe**, $w \in \mathbb{R}$
- **Center**, $\mathsf{c} = [c_1, c_2] \in \mathbb{R}^2$
- **Density**, $d \in \mathbb{R}$





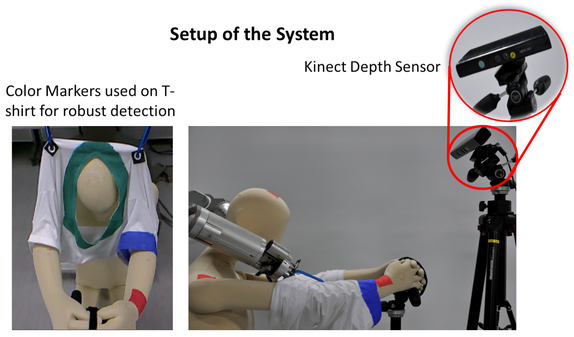
Human-Cloth relationship low dimensionally represented using topology coordinates:

- T-shirt collar and Mannequin's Head
- T-shirt collar and Mannequin's Body
- T-shirt sleeve and Mannequin's Shoulder

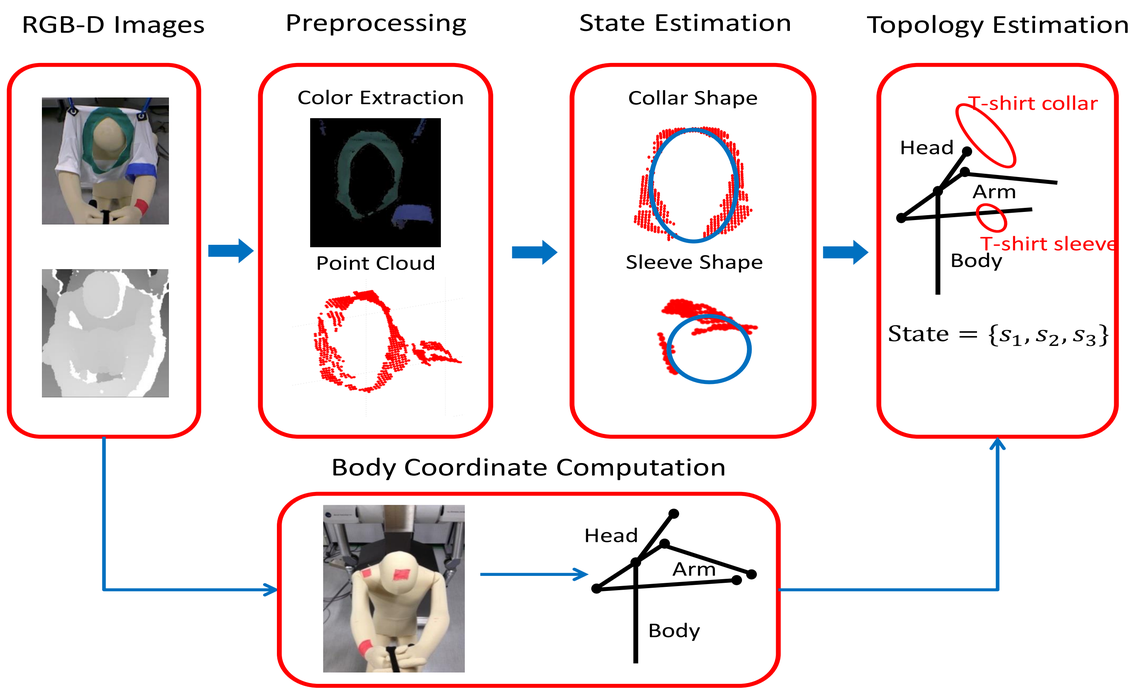
Proposed Method

Experimental Setup

- Human-Cloth relationship observed using **Kinect depth sensor**.
- **Color markers** used on T-shirt and Mannequin to ensure robust estimation.

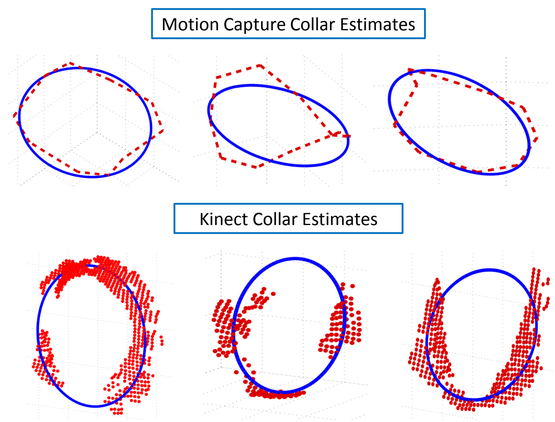


Proposed Method



T-shirt state estimation

- T-shirt collar and sleeve shape compactly represented using **Ellipses**.
- Generic 3D conic fitting approach proposed Shakarji et. al. [3] used for this purpose.



Experimental Results

Robustness of Topology Space to Measurement Noise

Robustness evaluated by comparing rewards obtained in *Cartesian* and *Topological* space.

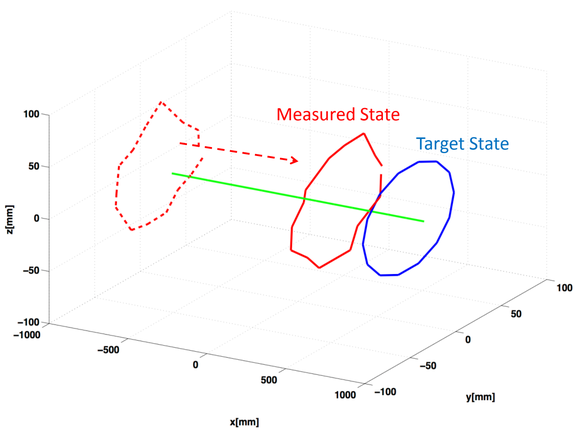
- Reward function in Cartesian Space:

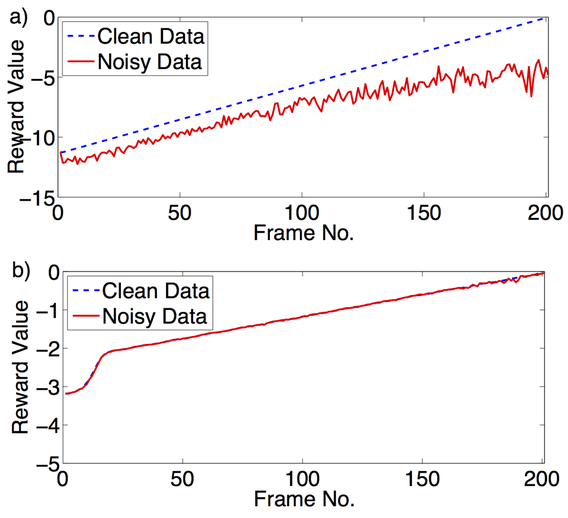
$$r(o_t) = -\sqrt{(o_t - o_{target})^T \Sigma_o^{-1} (o_t - o_{target})} \quad (1)$$

- Reward function in Topology Space:

$$r(s_t) = -\sqrt{(s_t - s_{target})^T \Sigma_s^{-1} (s_t - s_{target})} \quad (2)$$

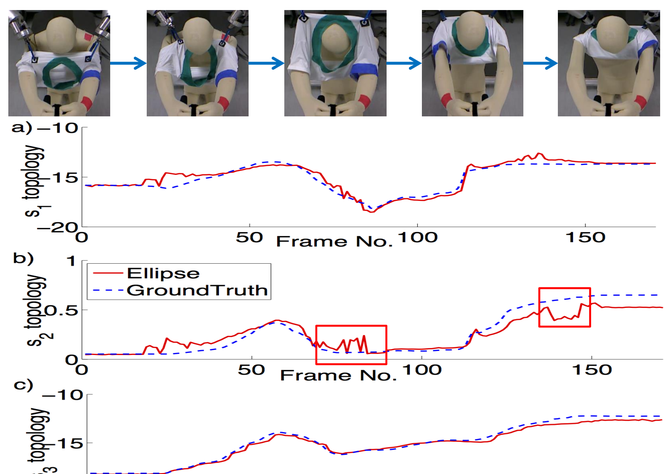
Simulation Experiment





Accuracy of Proposed Method

- Accuracy of proposed method evaluated by comparing our estimates with the ground truth.
- **Ground Truth**: Motion Capture System with 7 IR Cameras, 10 IR Markers used on T-shirt collar and 1 IR Marker on T-shirt sleeve.



Parameter	Pearson Corr	RMS Error
s_1 topology	0.9364	0.5955
s_2 topology	0.8857	0.1247
s_3 topology	0.9889	0.3529

- Proposed method provides reliable estimates in real-time (28-30 fps).
- However, there are jitters due to inherent noise in depth sensor.

Future Work

- Bayesian estimation of Human-Cloth relationship using *Proprioceptive* information of robot.
- Develop motor skills learning algorithm by incorporating real-time estimates.

References

[1] T. Tamei, T. Matsubara, A. Rai, and T. Shibata, "Reinforcement learning of clothing assistance with a dual-arm robot" in *Proc. of the 11th IEEE-RAS Int. Conf. on Humanoid Robots, pp. 733-738,* 2011.

[2] E. S. L. Ho and T. Komura, "Character motion synthesis by topology coordinates," in *Proc. of EUROGRAPHICS2009, vol. 28, no. 2, pp. 299-308,* 2009.

[3] M. C. Shakarji, "Least-squares fitting algorithms of the NIST algorithm testing system.", in *Journal of Research-National Institute of Standards and Technology 103,* 1998.