Robotic cloth manipulation for clothing assistance task using Dynamic Movement Primitives

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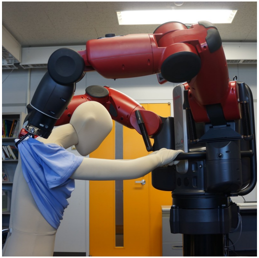
Outline

Introduction

- Clothing assistance is a basic and important assistance activity in the daily life of the elderly and disabled people
- Need of robotic clothing assistance is growing



Major challenges involved

- Close interaction of the robot with non-rigid clothing article
- Safe human-robot interaction
- Accurate estimation of human-cloth relationship

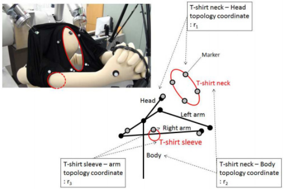
Related Works

Towner *et al.*[1], Identifying and manipulating clothing article by dual-arm robot

- ✓ Used Hidden Markov Model for tracking
- ✓ Triangulated mesh model for simulating clothing article
- × Highly depends on simulated contour information.

Tamei *et al.*[2], Clothing assistance with dual-arm robot

- ✓ Used Reinforcement learning (RL)
- ✓ Topology coordinates for human and cloth extremities relationship
- × Limited generalization capability for new postures



[1] Marco Cusumano-Towner et al. "Bringing clothing into desired configurations with limited perception". In: *Robotics and Automation (ICRA), 2011 IEEE International Conference on*. IEEE. 2011, pp. 3893–3900.

[2] Tomoya Tamei et al. "Reinforcement learning of clothing assistance with a dual-arm robot". In: *Humanoid Robots (Humanoids), 2011 11th IEEE-RAS International Conference on*. IEEE. 2011, pp. 733–738.

Dynamic Movement Primitives (DMP)

DMP in a nutshell

- It is used for generating a control signal to guide the real system[3]
- It can represent *nonlinear* motion with a set of differential equations

The system is defined as

$$\ddot{y} = \alpha_y(\beta_y(g - y) - \dot{y}) + f \tag{1}$$

where:

- y is system state and g is goal state
- α and β are gain terms
- f is nonlinear function defined over time

f is a function of *canonical system*, denoted by x as $\dot{x} = -\alpha_x x$

[3] Stefan Schaal. "Dynamic movement primitives-a framework for motor control in humans and humanoid robotics". In: *Adaptive Motion of Animals and Machines*. Springer, 2006, pp. 261–280.

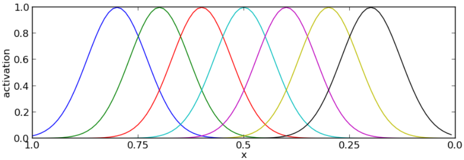
Forcing function f

f is defined as

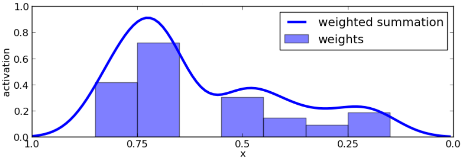
$$f(x,g) = \frac{\Sigma_{i=1}^{N}\psi_i w_i}{\Sigma_{i=1}^{N}\psi_i} x(g - y_0) \tag{2}$$

where:

- y_0 is the initial state of the system
- w_i is a weighting for a given basis function ψ_i
- $\psi_i = \exp\left(-h_i\,(x - c_i)^2\right)$ is Gaussian with mean c_i and variance h_i



ψ Activation



Weighted Summation

Imitating a desired path

The desired forcing term f which affects the system acceleration, is written as

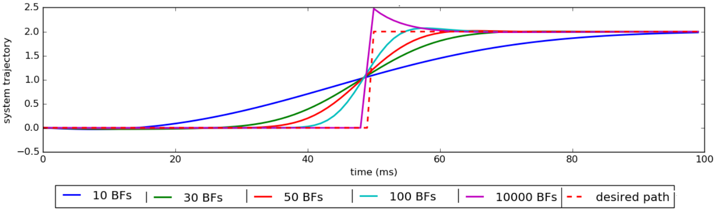
$$\mathbf{f}_d = \ddot{\mathbf{y}}_d - \alpha_y(\beta_y(g - \mathbf{y}) - \dot{\mathbf{y}}) \tag{3}$$

where

- $\mathbf{y}_d$ is desired trajectory, given by $\ddot{\mathbf{y}}_d = \frac{\partial}{\partial t}\dot{\mathbf{y}}_d = \frac{\partial}{\partial t}\frac{\partial}{\partial t}\mathbf{y}_d$

Choose the weights over the basis functions i.e., minimize[4]

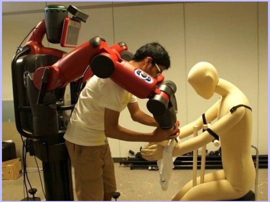
$$\Sigma_t \psi_i(t) \left[f_d(t) - w_i \left\{ x(t)(g - y_0) \right\} \right]^2 \tag{4}$$



[4] Stefan Schaal, Christopher G Atkeson, and Sethu Vijayakumar. "Scalable techniques from nonparametric statistics for real time robot learning". In: *Applied Intelligence* 17.1 (2002), pp. 49–60.

Workflow of *Robotic cloth manipulation* task

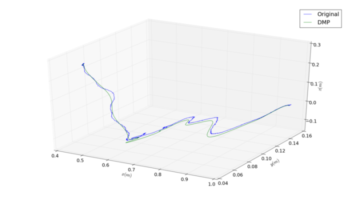
Teaching Phase



A demonstration is performed by moving the Baxter arms in the appropriate trajectory

Learn Trajectory

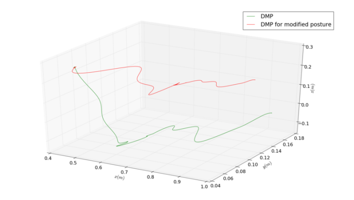
Baxter Left Arm Trajectory



Recorded trajectory is parameterized by DMP

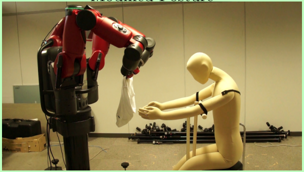
DMP Generalization

DMP Trajectory



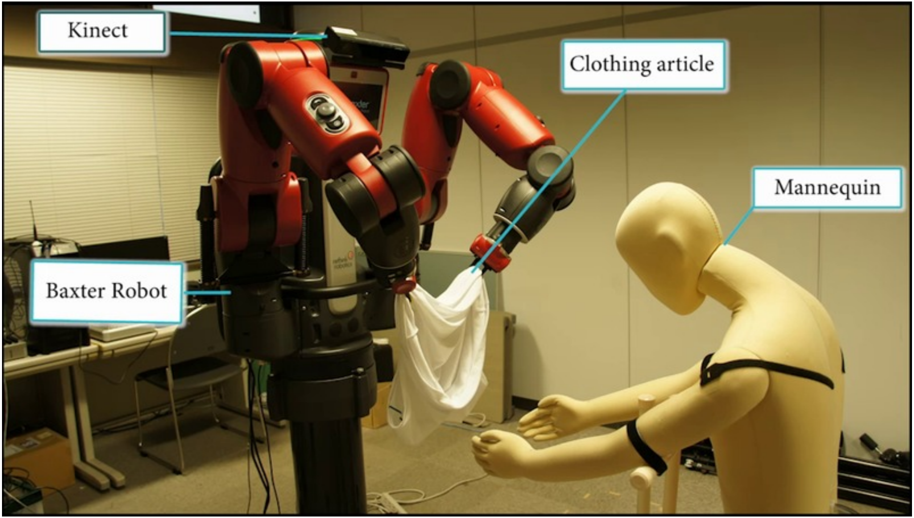
Testing Phase

Modified Posture

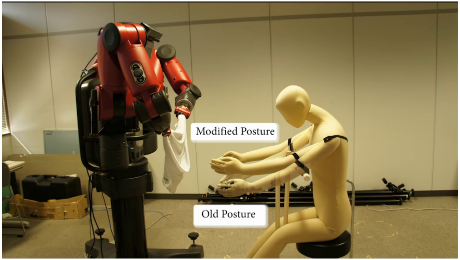


DMP can accomodate any posture by changing goal parameter

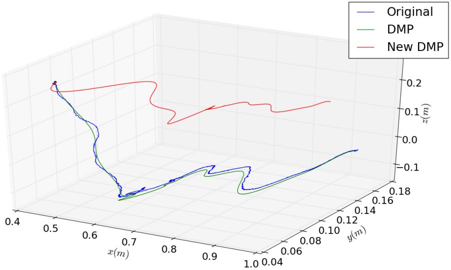
Setup



Experiments and results



Old & modified posture of mannequin

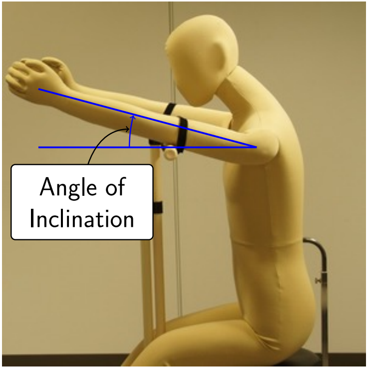


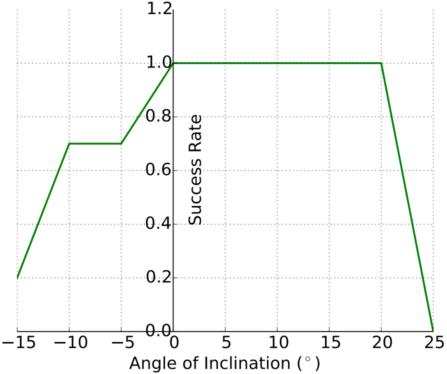
Left arm trajectories of Baxter Robot

Video demonstration

Accuracy measurement

Angle of Inclination measures the bending of arms w.r.t. horizontal line in two-dimensional space



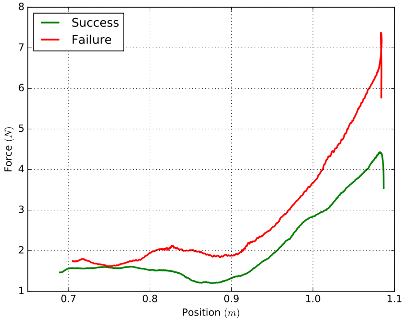


Failure detection using end-effector forces

Procedure

1. Each trajectory is computed by calculating the mean.
2. The force value is norm of force applied in all three Cartesian directions.

A failure scenario



Forces acting on left arm of Baxter

Conclusion and Discussion

- Baxter APIs[5] are used to get the end-effector forces. Raw forces are found noisy in nature.
- Result shows that DMPs are able to generalize the movement trajectory
- Proposed failure detection method by using force information can detect failures
- DMP should incorporate orientation information as well

[5] Cliff Fitzgerald. "Developing baxter". In: *Technologies for Practical Robot Applications (TePRA), 2013 IEEE International Conference on*. IEEE. 2013, pp. 1–6.

Future work

- Make approach more robust by using combination of visual and force information
- Need for designing an adaptive controller
  - For real-time tracking of mannequin
  - To adapt various failure scenarios

Acknowledgments

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Thanks for your attention!

Any questions?

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