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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

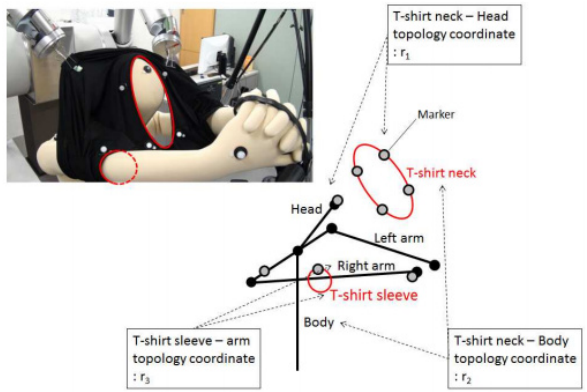
Related Works

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
- × Simple manipulations such as gripping using one arm only

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.

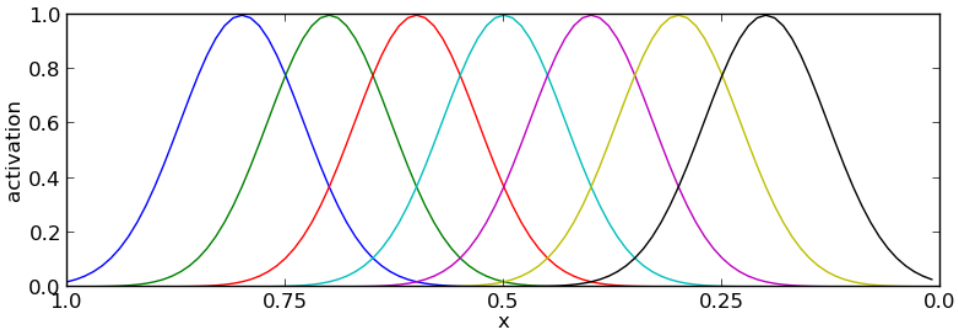
Forcing function f

f is defined as

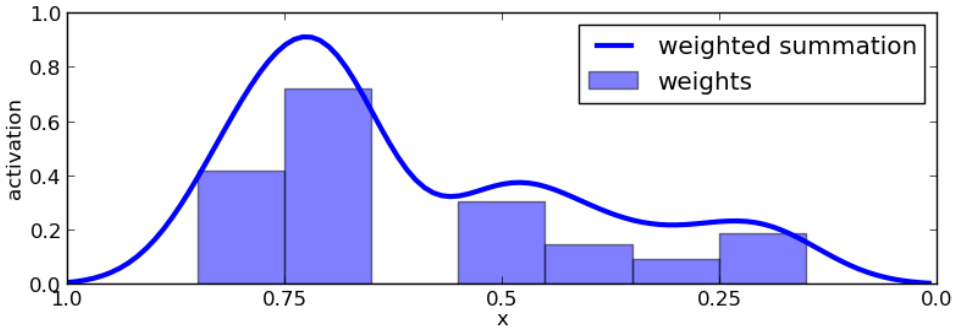
$$f(x, g) = \frac{\Sigma_{i=1}^{N} \psi_i w_i}{\Sigma_{i=1}^{N} \psi_i} x(g - y_0) \tag{2}$$

where:

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

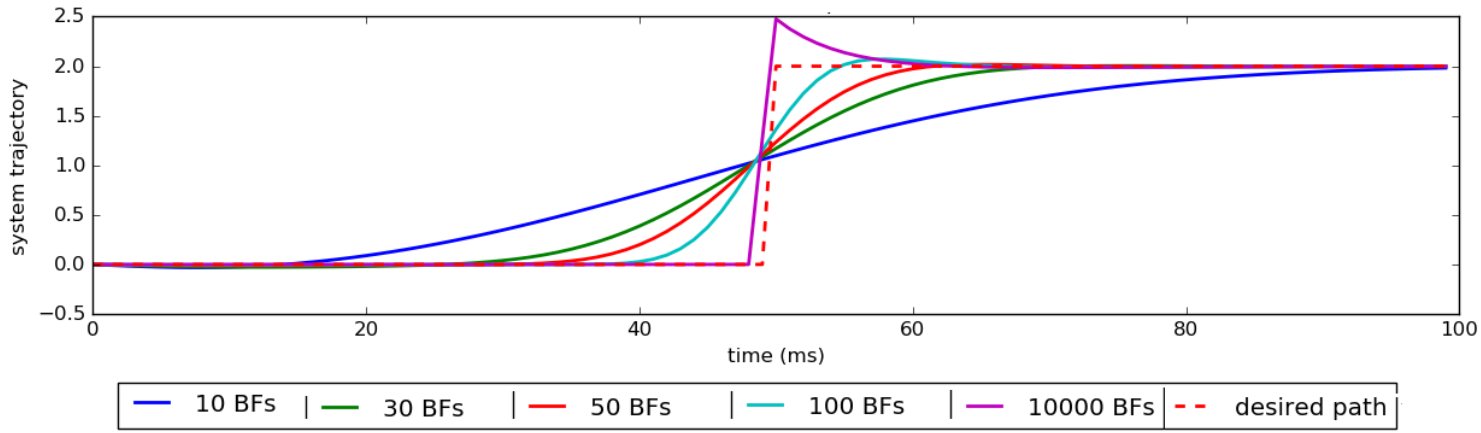
$$\mathbf{f}_d = \ddot{\mathbf{y}}_d - \alpha_y(\beta_y(g - \mathbf{y}) - \dot{\mathbf{y}}) \tag{3}$$

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]

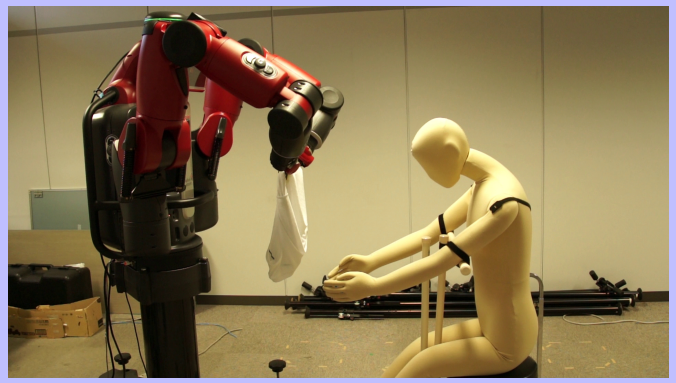
$$\Sigma_t \psi_i(t) \left[f_d(t) - w_i \left\{x(t)(g - y_0)\right\}\right]^2 \tag{4}$$



[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

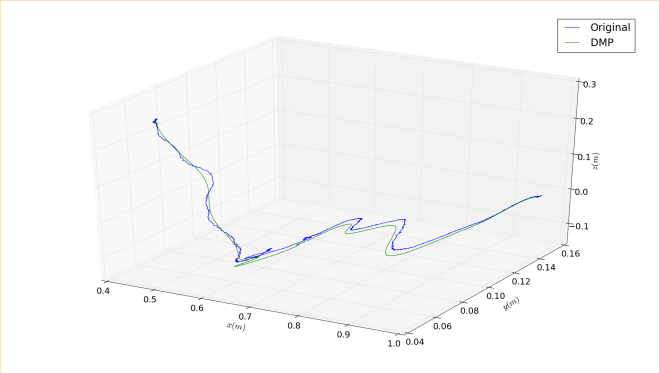
Teaching Phase



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

Trajectory Parameterization

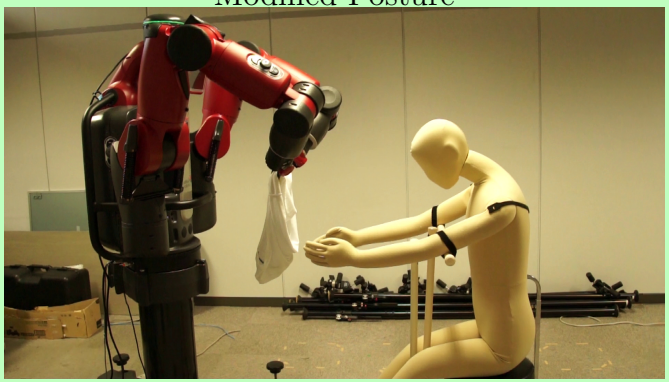
Baxter Left Arm Trajectory



Recorded trajectory is parameterized by DMP

Testing Phase

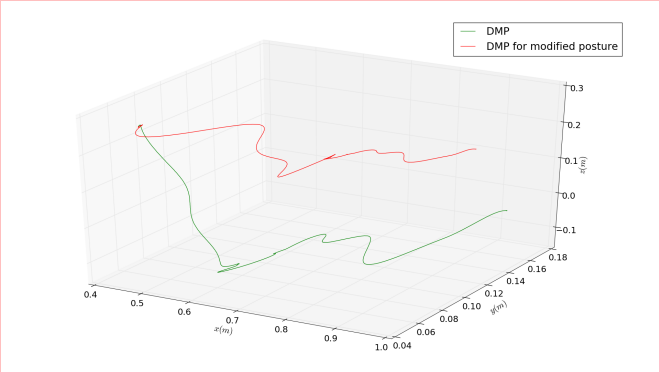
Modified Posture



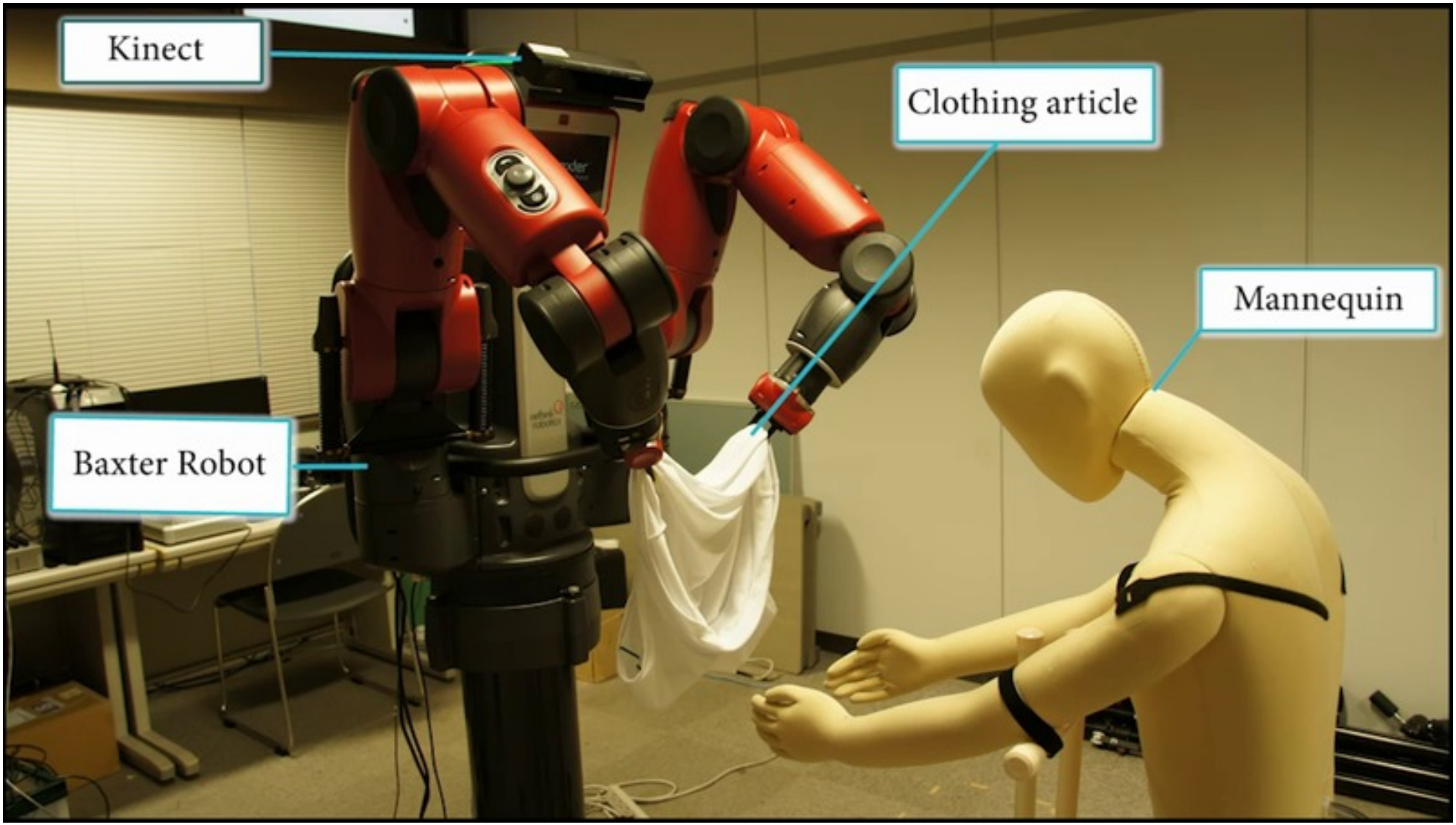
DMP can accomodate any posture by changing goal parameter

DMP Generalization

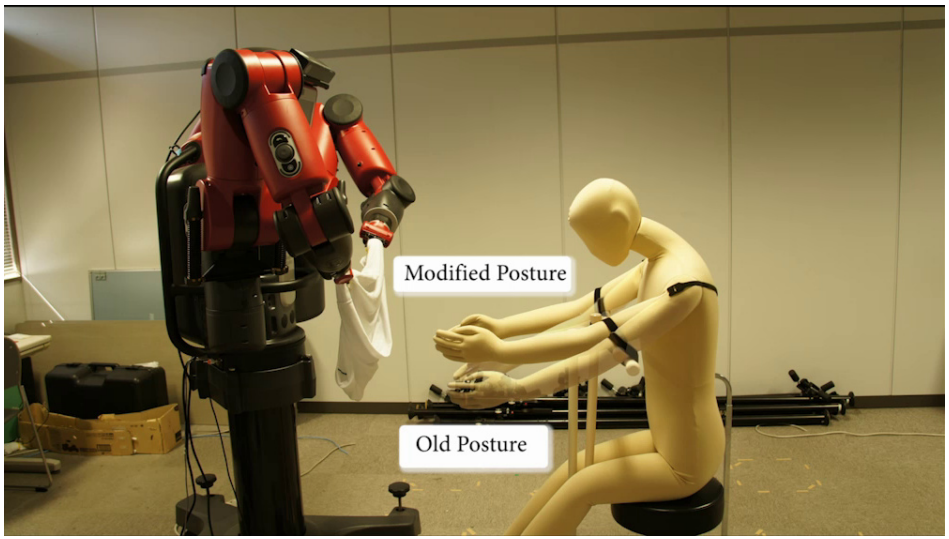
DMP Trajectory



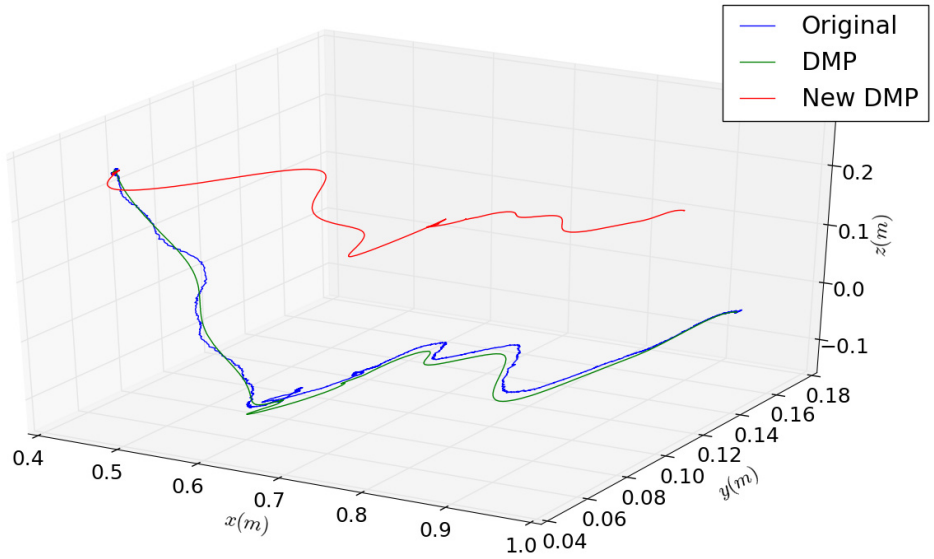
Setup



Results



Old & modified posture of mannequin



Left arm trajectories of Baxter Robot

Video demonstration

Conclusion and Discussion

- Result shows that DMPs are able to generalize the movement trajectory
- The converted trajectory from Cartesian Space to Joint Space was not smooth in some regions
  - It was calculated using TRAC_IK[5]
- Also real-time tracking of mannequin is required

[5] Patrick Beeson and Barrett Ames. "TRAC-IK: An open-source library for improved solving of generic inverse kinematics". In: *Humanoid Robots (Humanoids), 2015 IEEE-RAS 15th International Conference on.* IEEE. 2015, pp. 928–935.

Tentative Research Plan

Task / Year	2016	2017							
Main task / Sub task	December	January	February	March	April	May	June	July	August
Design Operational space controller: Implement OSC									
Design Operational space controller: Null-space controller									
Design Operational space controller: Real-time DMP generation									
Detect failure scenarios: Clothing article gets stuck									
Detect failure scenarios: Robot-mannequin collision									
Real-time adaptation: Tracking of mannequin									
Thesis writing									

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Thanks for your attention!

Any questions?

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