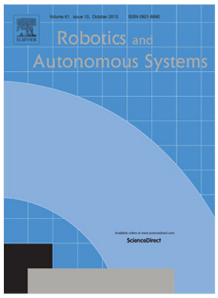


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Emmanuel Pignat, Sylvain Calinon

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# Learning adaptive dressing assistance from human demonstration

**Emmanuel Pignat and Sylvain Calinon**

*Idiap Research Institute, Martigny, Switzerland*

{emmanuel.pignat, sylvain.calinon}@idiap.ch

**Abstract**

For tasks such as dressing assistance, robots should be able to adapt to different user morphologies, preferences and requirements. We propose a programming by demonstration method to efficiently learn and adapt such skills. Our method encodes sensory information (relative to the human user) and motor commands (relative to the robot actuation) as a joint distribution in a hidden semi-Markov model. The parameters of this model are learned from a set of demonstrations performed by a human. Each state of this model represents a sensorimotor pattern, whose sequencing can produce complex behaviors. This method, while remaining lightweight and simple, encodes both time-dependent and independent behaviors. It enables the sequencing of movement primitives in accordance to the current situation and user behavior. The approach is coupled with a task-parametrized model, allowing adaptation to different users' morphologies, and with a minimal intervention controller, providing safe interaction with the user. We evaluate the approach through several simulated tasks and two different dressing scenarios with a bi-manual Baxter robot.

## 1. Introduction

One of the key abilities that will allow a wider spread of assistive robotics is learning and adaptation. In the case of assisting a person to dress, the robot should for example be able to adapt to different morphologies, pathologies or stages of recovery, implying different requirements for movement generation and physical interaction. This behavior is person-dependent, and cannot be pre-engineered (it is not fixed in time). It must instead continuously adapt to the user by considering acclimating or rehabilitation periods and aging. This requires the robot to represent dressing skills with a flexible model allowing adaptation both at the level of the movement and impedance parameters (e.g., based on the height of user or preferred forces), and at the level of the procedure (e.g., reorganization of the sequence of actions).

This assistance is currently provided by healthcare workers, which is not always convenient. From the worker perspective, there is a lack of employees dedicated to this service, while the activity takes time and is not particularly gratifying. From the patient's perspective, such assistance is often viewed negatively because it drastically reduces the sense of independence of the person (e.g., the person cannot go out of her own free will because of this dependence to another person for getting dressed). Providing robots with dressing assistance capabilities would have benefits on both sides, but it is not possible to preprogram all the dressing behaviors and requirements in advance. In this context, the programming by demonstration (PbD) paradigm provides a human-oriented solution to transfer such assistive skills from a non-expert user to the robot. This can be achieved by means of kinesthetic teaching or motion capture system, where several demonstrations of the task executed in various situations can be used to let the robot acquire the person-specific requirements and preferences rapidly.

In PbD, skills are generally decomposed into elementary building blocks or movement primitives (MPs) that can be recombined in parallel and in series to create more complex motor programs. They are particularly suitable to generate motion trajectories. However, in order to tackle the highly multimodal interaction involved in assistive tasks, the notion of movement primitives should be enlarged to a richer set of behaviors including reaction, sensorimotor and impedance primitives.

In particular, such a model should also be able to encode both time-independent and time-dependent behaviors. A typical example of time-independence in this human-centric context arise when holding a coat and waiting for someone to come; the duration of the associated movement primitive to help the person should here be triggered by the proximity and attention of the user, and is thus, in this case, time-independent. Other parts of the skill are in contrast time-dependent when a movement needs to be completed after being initiated, which typically appears when more dynamic features are required, such as slipping on pants. Often, a relative time dependence is required to guarantee a cohesive evolution of the movement (i.e., with a local time instead of an absolute