A COMPUTATIONAL MODEL OF ARM TRAJECTORY MODIFICATION USING DYNAMIC MOVEMENT PRIMITIVES

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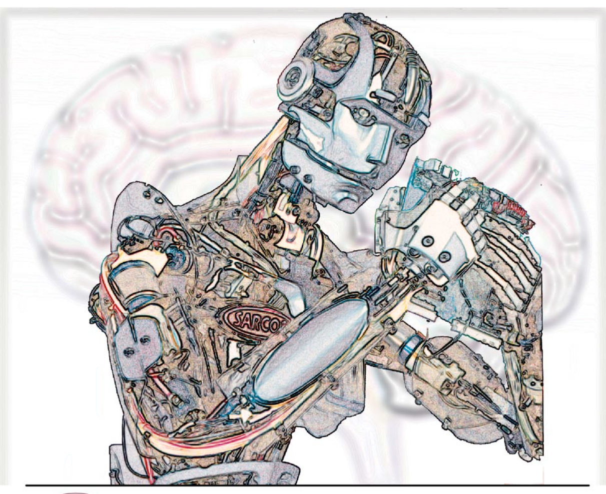


Computational Learning and Motor Control Lab

Peyman Mohajerian, Heiko Hoffmann, Michael Mistry, Stefan Schaal
Computer Science, Neuroscience, and Biomedical Engineering, University of Southern California,
Los Angeles, CA 90089-2520 & ATR Computational Neuroscience Laboratories, Kyoto, Japan
http://www-clmc.usc.edu/

Motivation

Introduction:

An open issue in the neural control of movement is how humans generalize a previously learned behavior to new or altered situations. One method to investigate this is the double-step target displacement protocol which shows how an unexpected upcoming new target modifies an ongoing discrete movement.

Hypothesis for online goal adaptation:

+ Second movement is superimposed on the first movement (Henis and Flash, 1995)
+ First movement is aborted and the second movement is planned to smoothly connect the current state of the arm with the new target (Hoff and Arbib, 1992)
+ Second movement is initiated by a new control signal that replaces the first move ment's control signal, but does not take the state of the system into account (Flanagan et al., 1993)
+ Second movement is initiated by a new goal command, but the control structure stays unchanged, and feed-back from the current state is taken into account (Hoff and Arbib, 1993)

Goals:

Show that online correction and the observed target switching phenomena can be accomplished by changing the goal state of an on-going Dynamic Movement Primitive (DMP), without the need to switch to different movement primitives or to re-plan the movement.

This poster addresses using DMPs as a parsimonious movement generalization paradigm to investigate online movement correction

Methods

Experimental Setup:

- Endpoint tracking using Newton Lab Color Vision System at 60 Hz.
- Psychtoolbox software with MatLab for generating 3D anaglyph visual stimuli.

Procedure:

Starting from a visually displayed start point, subjects perform reaching movement to a given target point. Subjects were instructed to immediately move to the target as soon as it was displayed. In 50% of the trials, the target suddenly switched to a new target. The interstimulus interval (ISI) between the onset of the first and second target was varied between 30, 50, 100 and 200ms across blocks. Each subject performed four blocks (80 trials), presented in a randomized way. Model Equations based On Dynamic Movement Primtiives:

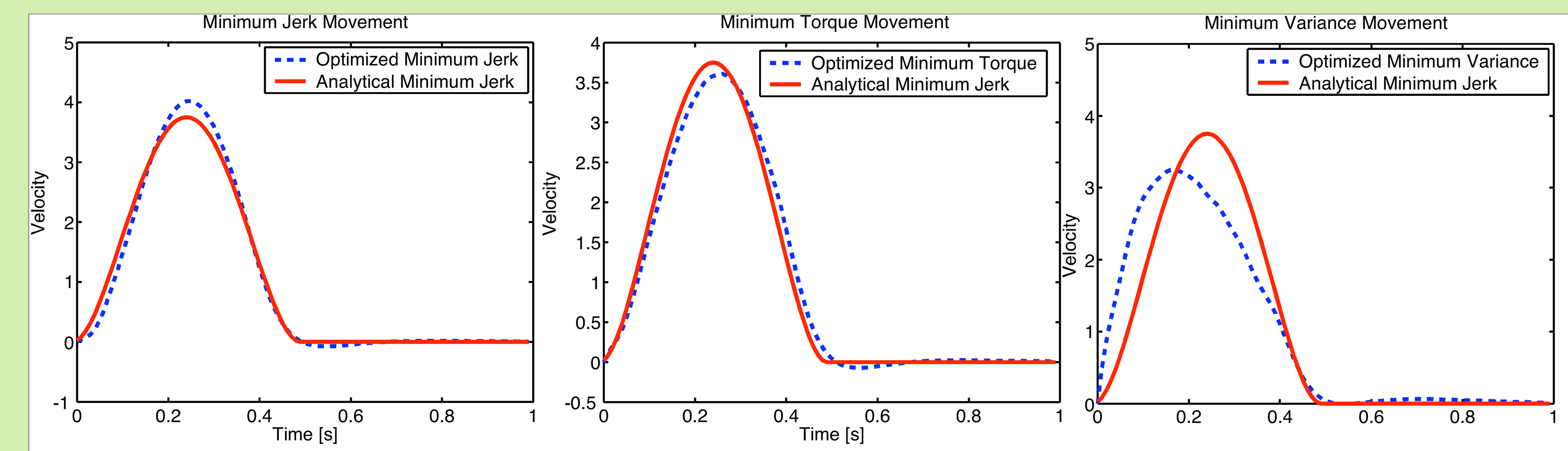
x- position, v- velocity
x_0- start position, g- goal position
$\mathbf{K}$ - similar to spring constant
$\mathbf{D}$ - damping term, critically damped
ψ_i - gaussian basis function with center and heights of c_i, h_i
θ -phasic variable between 0 to 1
α -time constant

$$\dot{v} = \theta\,\mathbf{K}\left(\frac{\sum_i \psi_i(\theta) w_i}{\sum_i \psi_i(\theta)} + x_0 - x\right) + (1-\theta)\mathbf{K}(g-x) - \mathbf{D}v$$

$$\dot{x} = v$$

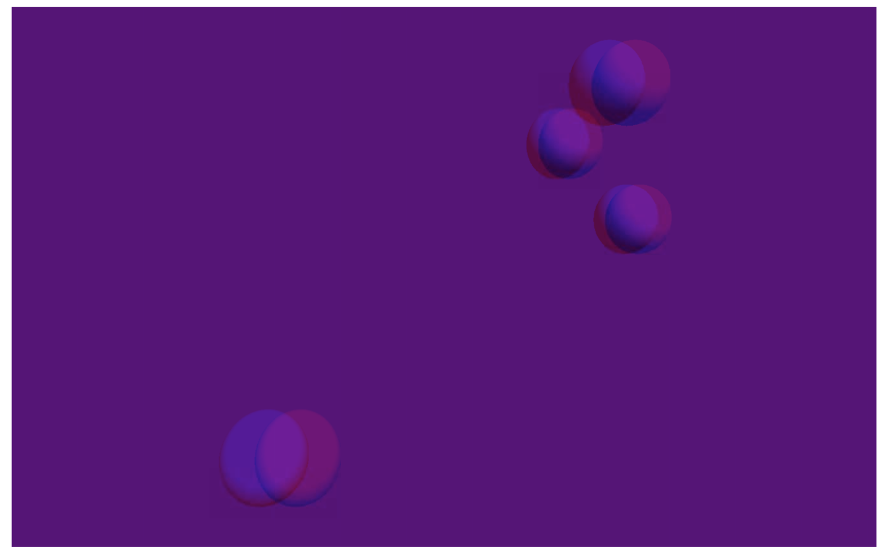
$$\dot{\theta} = -\alpha\,\theta$$

$$\psi_i(\theta) = \exp\left(-h(\theta - c_i)^2\right)$$



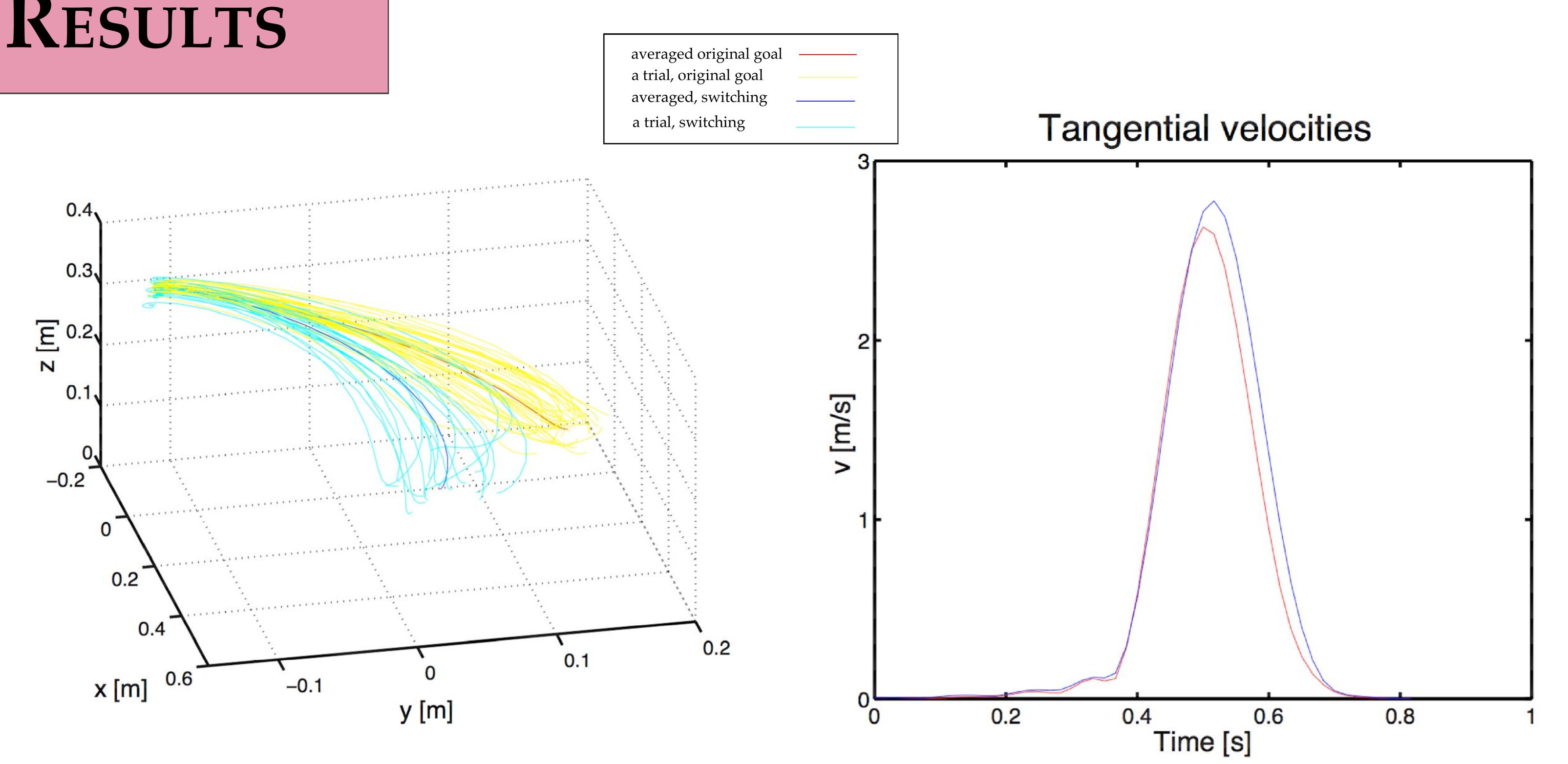
Dynamic Movement Primitives are a general representation for kinematic movement planning with learnable linear parameters w_i. The parameters can be acquired, e.g., from imitation learning, but also from general optimization frameworks, as shown in the plot above. In these plots. we simulated a 1 DOF linear movement system with mass, stiffness, and damping parameters. The parameters w_i were optimized according to different criteria that were suggested in the literature, e.g., minmum jerk, minimum torque change, and minimum endpoint variance (Flash and Hogan 1985; Uno et al. 1989; Harris and Wolpert 1998).

View of the experimental setup. A subject is pointing at the initial target while the two cameras are tracking the green sphere that he is holding. The cubic foam with the green ball on top is used during calibration of the cameras

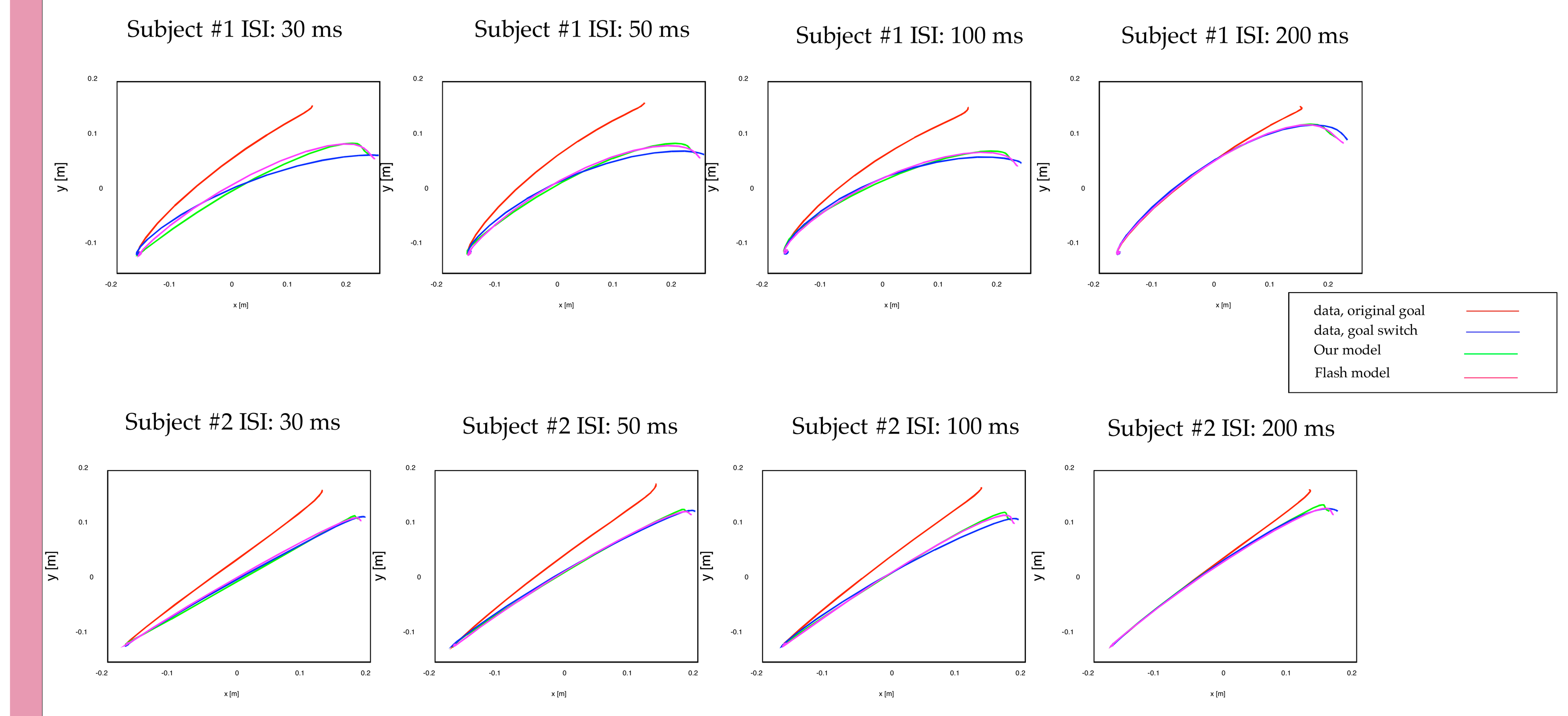


Subject's view of the display monitor. In the lower left is the sphere for the initial end-effector position, in the upper right is the position of the primary target (in the middle) and the two secondary targets orthogonal to it. Obviously at any point in time subjects can only see one of the spheres.

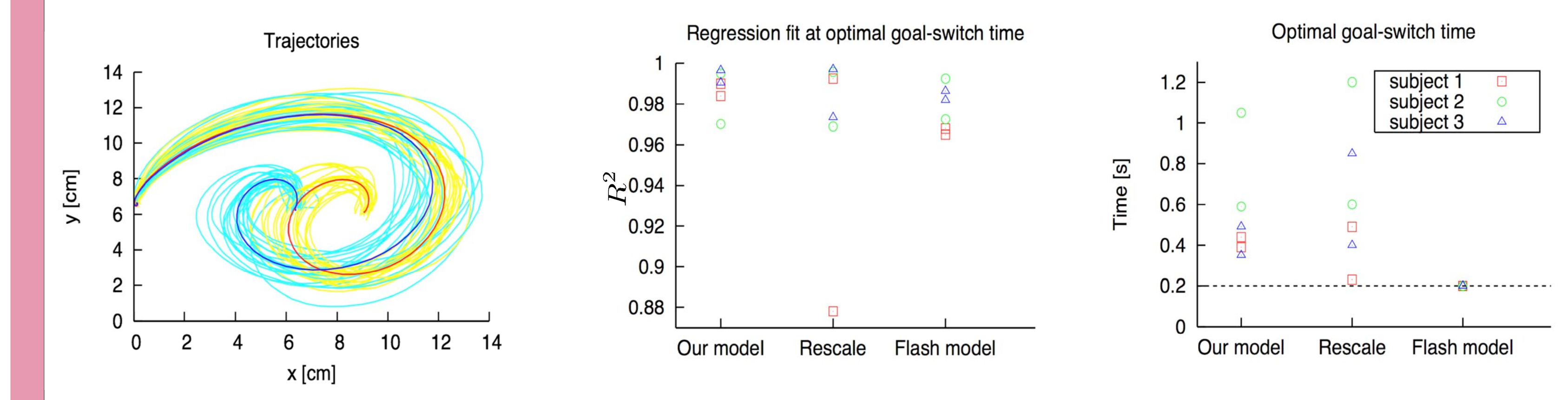
Results



On the left trial by trial and the averaged trajectories for one of the subject for ISI value of 30 ms.
On the right, averaged velocity profile for the same set of data. Bell shaped velocity characteristic is preserved during target switching.



Trajectories of the goal directed movement for two subjects for different ISI values, averaged across all trials. In both subjects as the ISI increases the initial direction of the movement moves toward the first target.
Our model is comparable to Flash's, but a straight movement is not sufficient to distinguish between models. We will extend our experiment to more complex target switches, and also more complex movements (e.g., like a spiral).



Discussion

In this (preliminary) work, DMPs were used as a model for target switching experiments. The model accounts for a target switch simply by updating the goal state of the DMP. There is no need for explicit replanning, re-optimization, super-position of other movement primtives, etc., to account for our data. Thus, DMPs seem to offer a very parsimonious account for movement control in dynamic environments. Further experiments will are needed to make this point in a richer repertoire of movements.

References:

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