Can Learning from Demonstration Approaches Encode and Generalise Human Movements for Neurorehabilitation?

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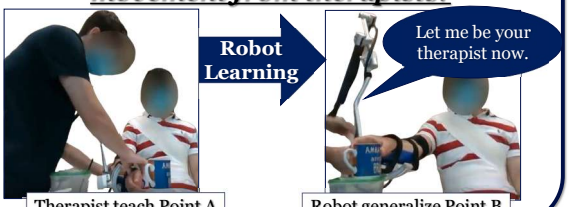
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Why customize pHRI in Rehabilitation?

Therapists customise rehabilitation [1] to orient patients to functional practice

However, therapist presence is always required.

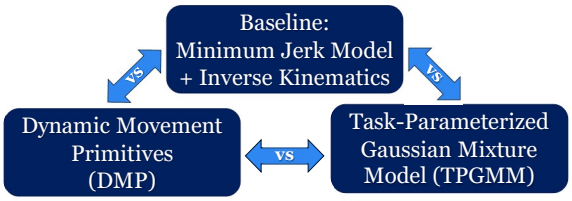
Can robots generalize demonstrated movement from therapists?



What's Missing in Rehab LfD?

1. Quality of encoded movement from basic LfD and record-repeat methods compared [2], but did not show generalization.
2. Dynamic Movement Primitives [3] generalised joint movement of rehabilitation robots but did not evaluate movement similarity.
3. Task-Parameterized Gaussian Mixture Model [4] can generalize 3D movement, but applications in joint space not explored.

LfD Algorithms

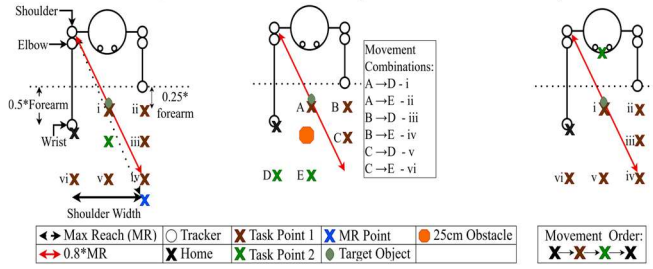


Similarity of Reconstruction to Actual movement

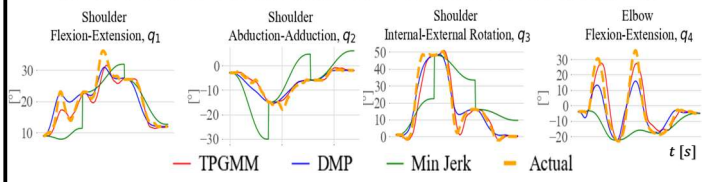
Movement Quality	Space	Similarity	Analysis
Joints Trajectory	Joint	Dynamic Time Warping (DTW)	Smaller similarity metric value
Swivel Angle Trajectory			
MARP		Δ	
Wrist Trajectory	Task	Hausdorff Distance (HD)	Closer similarity to actual movement
Spectral Arc Length (SAL)		Δ	
Time-to-peak speed (TTP)			

Exp. 1 – Compare LfD in Capturing Movement Quality for Task Variations

- Subjects to perform four different tasks with variations each.
- For each task, variations randomly selected for demo / test.



RESULTS: Reconstructed Joint Movement (Task 3)



RESULTS: Metric Comparison of LfD Algorithms

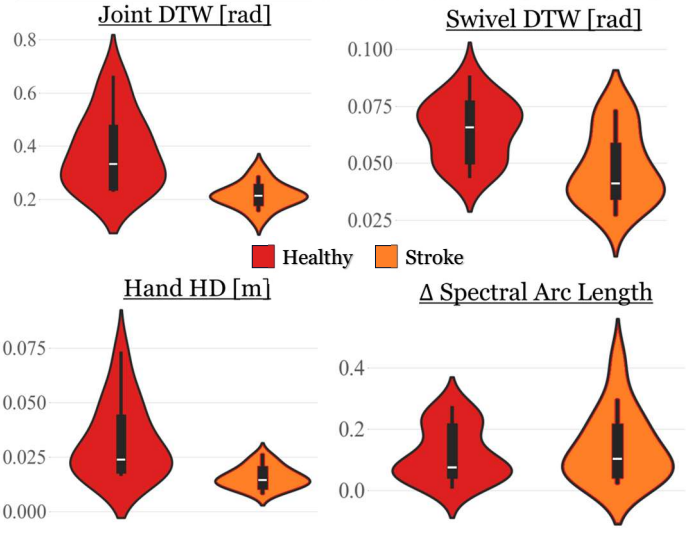
Metric	Mean Difference $i - j$			Best
$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$	TPGMM -Min Jerk	DMP -Min Jerk	TPGMM -DMP	
Task 3 – Obstructed Pick-Place				
Joints DTW (rad)	-3.150***	-2.244***	-0.906***	TPGMM
Swivel DTW (rad)	-0.369***	-0.236**	-0.133**	TPGMM
ΔMARP	-0.247**	-0.124*	-	-
Hand HD (m)	-0.056**	-0.023**	-0.033**	TPGMM
ΔSAL	-	-	-	-
ΔTTP	-	-0.061***	0.037*	DMP

➢ **TPGMM** outperforms DMP & Min Jerk in **generalising complex tasks (Task 3 – Obstacled Pick-Place).**
- TPGMM enrichens distribution from multiple observer frames (different start-end points).

Exp. 2 – TPGMM Capturing Patient Specificity

- Learn and reconstruct upper limb movement for *drinking task* with healthy and stroke subjects [5].

RESULTS: TPGMM Reconstruction (Healthy vs Stroke)



➢ **TPGMM** produces **more faithful encodings of stroke subjects'** movement quality compared to healthy subjects (except for Spectral Arc Length).
- Captured specificity of joint synergies and compensatory behaviour.
- Increased modelling complexity (Heathy: 20-63 kernels, Stroke: 38-92 kernels).

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[3] C. Lauretti et al., IEEE Robot. Autom. Lett., 2017
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