Personalized Robotic Training using Online Estimation of Human Motor Learning

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INTRODUCTION

Effectively modeling how people acquire and retain motor skills is crucial for advancing neurorehabilitation and advanced human-in-the-loop training. Previous studies [1] have proposed mathematical models to describe the underlying processes of motor learning and explain different behavioral phenomena. However, current estimation methods [2] typically fit these models to behavioral data offline and rely on entire data to estimate model parameters, which limits the ability to track the dynamic nature of the learning process. In this study, we present a new framework for modeling human motor learning in real time.

MATERIALS AND METHODS

We conducted a user study involving 10 participants who completed reaching tasks under visuomotor perturbations (Fig. 1A), using the Kinarm End-Point robotic system (Fig. 1B). To capture the underlying motor learning processes in real time, we implemented an online system identification approach based on the Kalman Filter (KF). This framework continuously estimated individual learning and forgetting rates as new data were acquired, allowing for a personalized and dynamically updated representation of each participant's learning.

RESULTS AND DISCUSSION

The proposed KF-based framework effectively captured the evolving dynamics of motor learning as indicated by the low RMSE (3.57°) between actual and predicted motor outputs. Moreover, it accurately estimated model parameters in real time, showing strong consistency with gold-standard offline estimation methods.

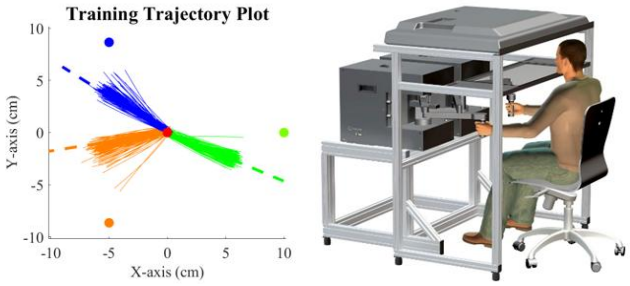

Fig 1: (A) Reaching under visuomotor perturbations (B) Kinarm End-Point Lab.

CONCLUSIONS

By estimating individual learning and forgetting rates in real time, our approach supports the development of intelligent, adaptive systems that personalize training based on each participant's performance, holding substantial promise for applications in rehabilitation and motor skill acquisition.

REFERENCES

[1] Smith et al.. "Interacting adaptive processes with different timescales underlie short-term motor learning."
[2] Albert et al "Estimating properties of the fast and slow adaptive processes during sensorimotor adaptation."