DOI: 10.3217/978-3-99161-050-2-237

# Unsupervised Manifold Stabilization Method for Across-Session Brain-Computer Interface Decoding

**Mohammadali Ganjali[1], Abed Khorasani[2], Alireza Mehridehnavi[1]***

[1]*Department of Biomedical Engineering Isfahan University of Medical Sciences, Isfahan, Iran;* [2]*Department of Neurology, Northwestern University Chicago, IL, 60611, USA;*

* P.O.Box: 8174673461 Isfahan, Iran. E-mail: mehri@med.mui.ac.ir

*Introduction:* Brain-computer interfaces (BCIs) aim to convert cortical activities into motor commands to operate external devices, offering hope for individuals with movement disorders such as spinal cord injury (SCI). However, a major challenge for real-time BCIs is the variability in neural activities across sessions, requiring frequent recalibration to maintain decoding accuracy. One solution involves projecting neural signal onto low-dimensional manifolds and aligning them using methods such as canonical correlation analysis (CCA). However, CCA relies on knowing the subject's true intentions, such as target direction, which is often impractical in real-world applications. To address this, we developed an unsupervised approach to estimate target direction prior to alignment.

*Material, Methods, and Results:* An automatic algorithm Unsupervised Neural Manifold Alignment Decoding (UnMAD), was proposed to decode movement parameters without requiring target labels. UnMAD integrates three main stages: (1) Dimensionality reduction for extracting manifolds, (2) Discrete trajectory decoding for predicting target labels, and (3) Continuous movement decoding for aligning and decoding. We evaluated the proposed approach against two baseline methods: a supervised decoder that calibrates using day-k neural and behavioral data, and an unsupervised algorithm called distribution alignment decoding (DAD). DAD matches predicted movements on day k with historical manifold distributions through distribution alignment techniques. The primary goal was to decode 2D velocity (Fig. 1 A) from the neural activity of the primary motor cortex of two monkeys (Monkey C and Monkey M) during a reach center-out task. UnMAD compensated for manifold variability across two different recording sessions in two monkeys, increasing the average correlation between manifolds from R=0.47 (before UnMAD) to R=0.97 (after UnMAD). In decoding movement velocities (Fig. 1B-D) UnMAD outperformed unsupervised DAD approach in the average decoding performance ($R^2$= 0.65 vs. 0.21). Also, UnMAD achieved 84% of the decoding performance of the CCA supervised method ($R^2$= 0.65 vs. 0.77).

*Conclusion:* UnMAD provides an unsupervised approach for stabilizing neural manifolds without requiring target labels, making it promising for clinical applications of BCIs for individuals with SCIs.

*Acknowledgments and Disclosures:* The authors declare no conflicts of interest.

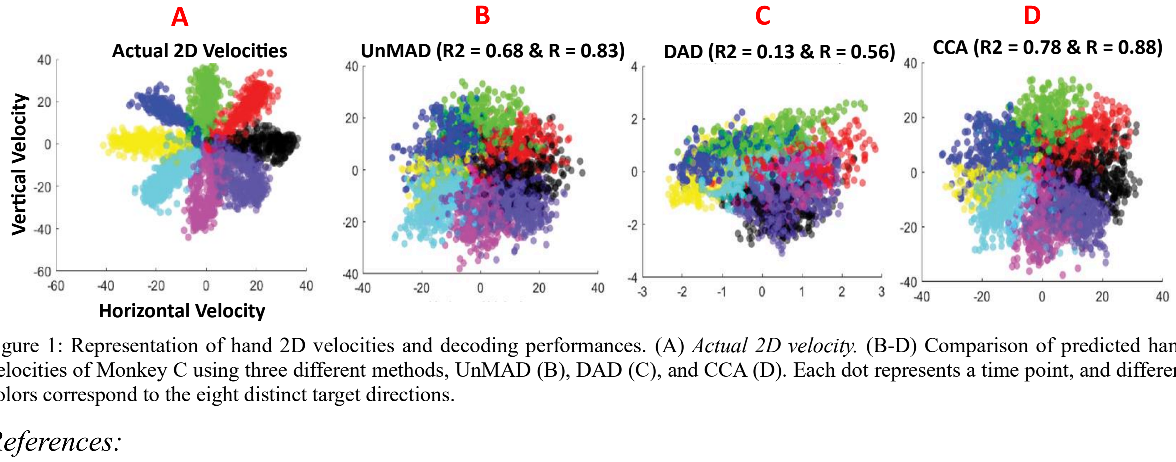


Figure 1: Representation of hand 2D velocities and decoding performances. (A) *Actual 2D velocity.* (B-D) Comparison of predicted hand velocities of Monkey C using three different methods, UnMAD (B), DAD (C), and CCA (D). Each dot represents a time point, and different colors correspond to the eight distinct target directions.

## *References:*

[1] Gallego JA, Perich MG, Chowdhury RH, Solla SA, Miller LE. Long-term stability of cortical population dynamics underlying consistent behavior. Nature neuroscience. 2020 Feb;23(2):260-70.

[2] Dyer EL, Gheshlaghi Azar M, Perich MG, Fernandes HL, Naufel S, Miller LE, Körding KP. A cryptography-based approach for movement decoding. Nature biomedical engineering. 2017 Dec;1(12):967-76.

[3] Ganjali M, Mehridehnavi A, Rakhshani S, Khorasani A. Unsupervised Neural Manifold Alignment for Stable Decoding of Movement from Cortical Signals. Int. J. Neural Syst.. 2024 Jan 1;34(1):2450006-1.





Published by Verlag der Technischen Universität Graz