

Decentralized Coupled Representation Learning

From local exploration to stable global structure

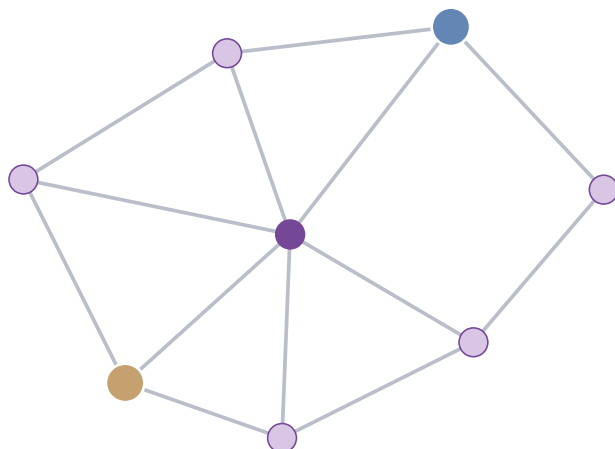
Zilin Li · Presenter

Weiwei Xu · Xuchun Tong · Xuanbo Lu · Xuanqi Zhao · Ge Zhang

Donghua University · Shanghai

Learning without a central view

LOCAL OBSERVATIONS



Agents move and observe only nearby information.

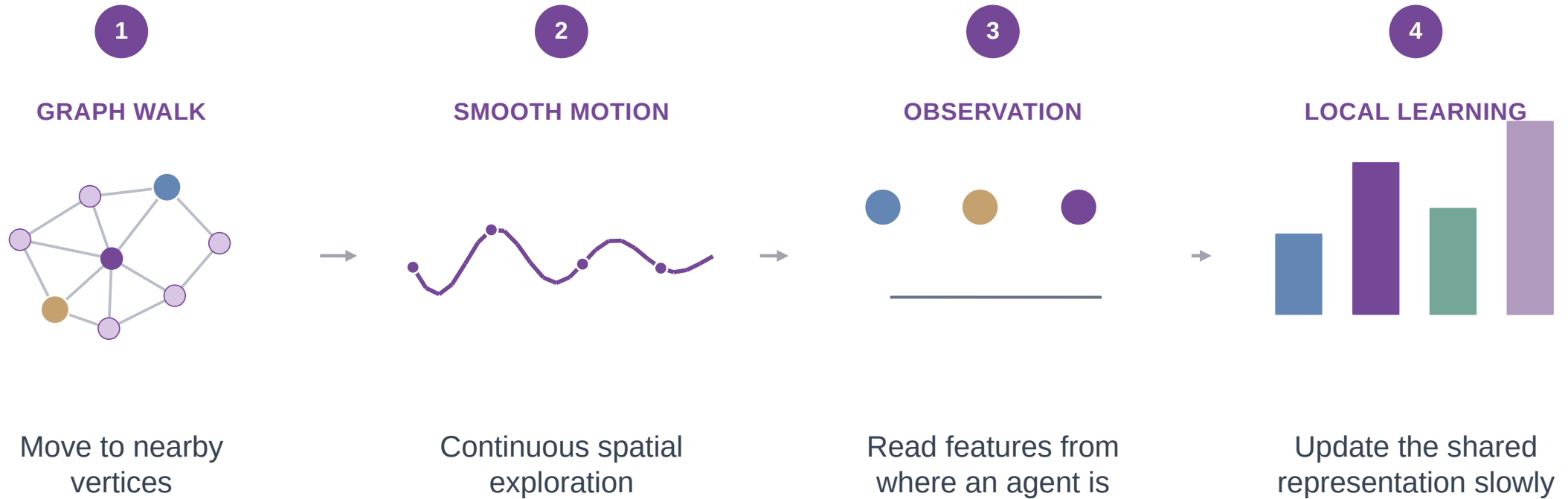
GLOBAL STRUCTURE



Yet we want a stable, low-dimensional representation.

The challenge: the data stream and the learner evolve together.

Explore fast. Learn slow.



Two time scales



Local walks approach a diffusion

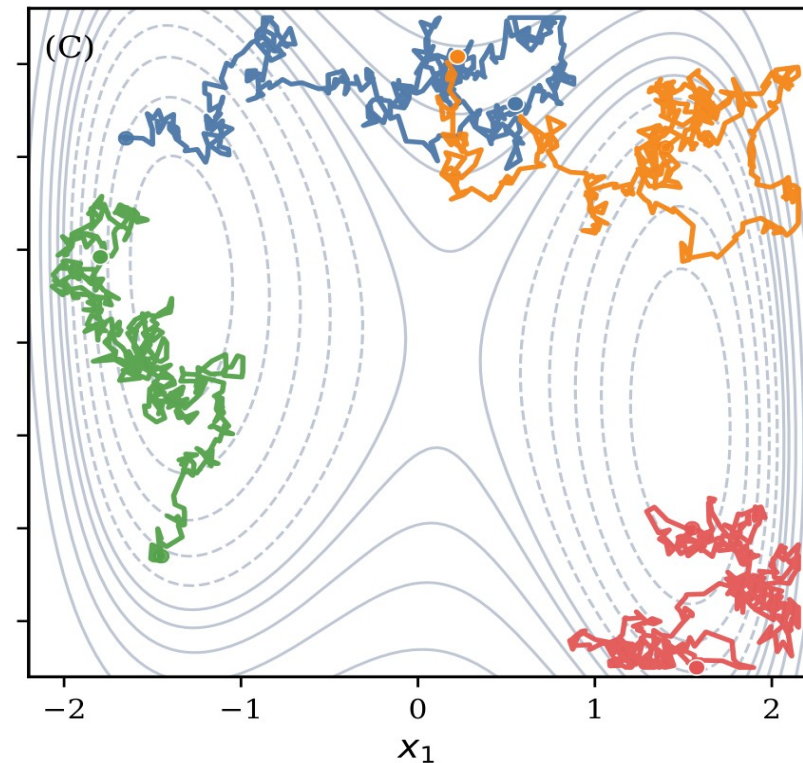
A geometric graph supports small, local jumps. As the graph becomes sufficiently dense, these jumps acquire a smooth large-scale description.

GRAPH GENERATOR

converges to

LANGEVIN GENERATOR

For smooth test functions, uniformly in probability under the paper's graph-scaling assumptions.



Representative Langevin paths · Fig. 1(C)

Slow learning has a stable averaged flow

On the slow time scale, rapid changes in the observations average out.

Fast fluctuations



A stable average



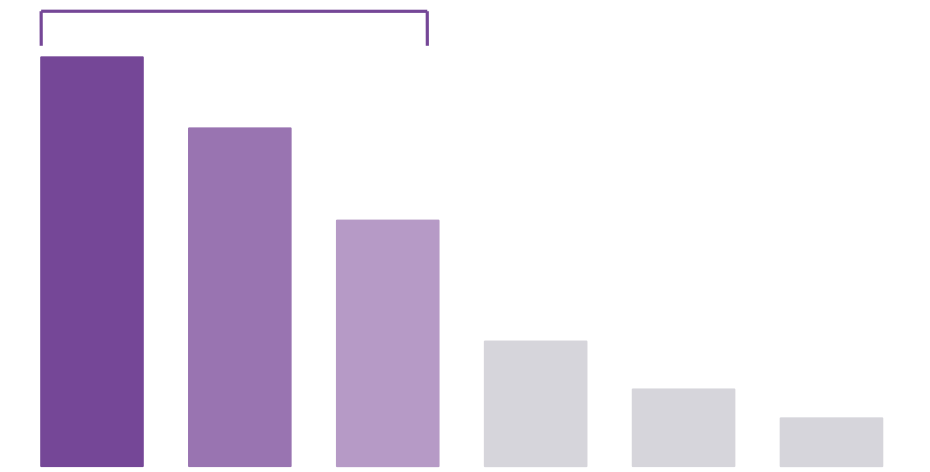
Schematic trend (not experimental measurements)

Orthogonality defect does not increase along the averaged dynamics.

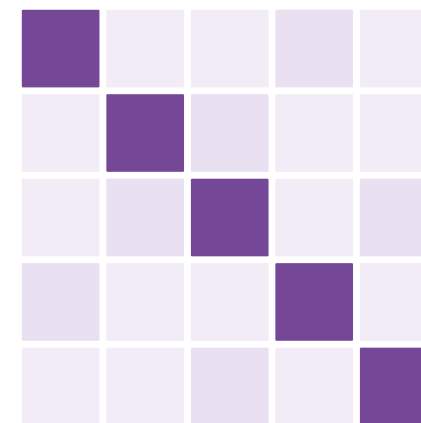
The leading subspace is selected

When the leading directions are separated by a spectral gap, the learned representation aligns with their subspace.

LEADING DIRECTIONS



ROTATED LATENT COVARIANCE

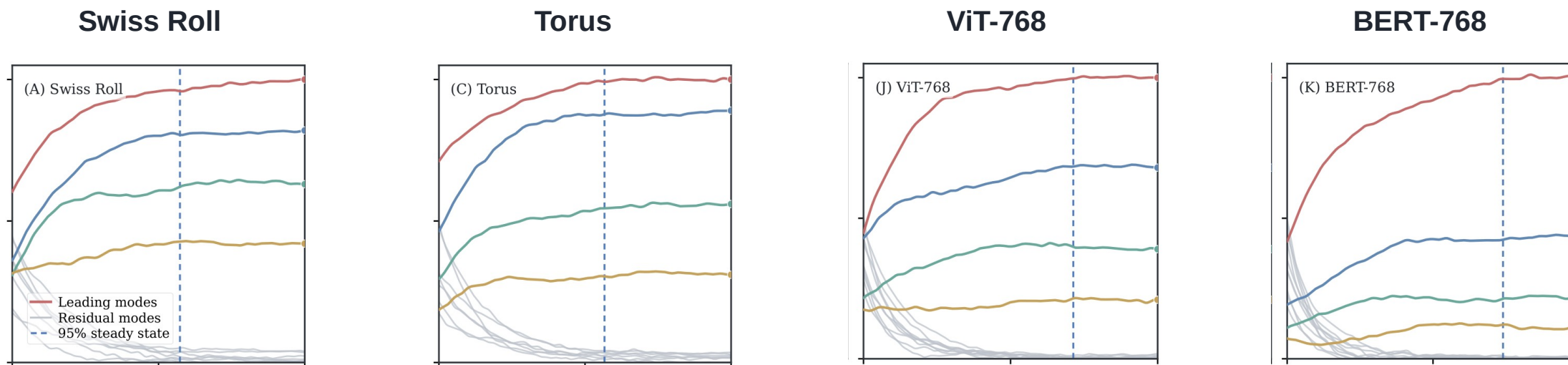


Only the diagonal remains
in a suitable latent basis.

The basis may rotate; subspace recovery does not require a unique set of axes.

Spectra stabilize across varied substrates

Selected panels from the paper's 12-substrate evaluation.



Leading modes settle while residual modes contract.

Original plots: Fig. 2 | 15,000 steps | dashed blue = 95% steady state

Both mechanisms matter

Lyapunov-violation rate on the controlled HD-GMM substrate (Table 2).



Without lateral inhibition the run diverges; violating the two-time-scale regime sharply increases violations.

Local interactions can reveal global structure

- 01 Local walks**
admit a continuous diffusion limit.

- 02 Slow representation updates**
follow a stable averaged flow.

- 03 A spectral gap**
selects the leading subspace.

Scope: smooth compact manifolds, time-scale separation, and linear subspace representations.

github.com/Lixeeone/Decentralized-Coupled-Representation-Learning