

M2 Internship – Neural Renormalization Group for Critical Phenomena

Host	LISN (AO team) and Inria Saclay (TAU team), Université Paris-Saclay, Orsay
Supervisors	[Cyril Furtlehner, Sergio Chibbaro]
Duration	5–6 months, spring 2027
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Context

Standard neural networks can locate the percolation threshold but fail to see the percolating cluster itself: they learn local density proxies, not the scale-dependent connectivity that defines the transition. The renormalization group (RG) suggests a remedy: apply the same local transformation recursively across scales.

We recently built a scale-shared encoder–decoder in which a single learned coarse-graining map is applied at every scale (*Neural Renormalization Group Flow for Percolation*, arXiv:2608.26764). Trained on lattices up to $L = 64$, it extrapolates to $L = 1024$, reconstructs the spanning cluster, and yields finite-size scaling with fitted $p_c \approx 0.5930$, $\nu \approx 1.34$ and $d_f \approx 1.887$. Its latent space shows critical fluctuations and an empirical flow from an unstable critical fixed point towards two stable phases. The internship aims to turn this empirical flow into a quantitative RG.

Objectives

The student will extend the model along one or more of these directions, depending on interests:

1. **Quantitative RG flow.** Locate the fixed points of the learned latent map, linearize it around the critical one, and extract the scaling exponents (e.g. $y_t = 1/\nu$) directly from its eigenvalues rather than from finite-size fits.
2. **Symmetries and normalization.** Build lattice symmetries (rotations, reflections) into the coarse-graining rule and control the normalization of the latent field, which the current model leaves free.
3. **Universality tests.** Train on site percolation and test on bond, other lattices, or correlated percolation; check whether the learned flow and exponents are shared.
4. **Beyond percolation.** Apply the architecture to directed percolation, the 2D Ising model, avalanche models with self-organized criticality, or general conformal theory problems.

The work combines Monte Carlo simulation (Newman–Ziff), deep-learning experiments in PyTorch, and finite-size scaling analysis.

Profile and application

We seek an M2 student in theoretical, statistical or computational physics with a solid background in statistical mechanics . Programming in Python is required; prior experience with machine learning is a plus but not necessary. The internship can lead to a PhD within the same project.

To apply, send a CV and transcripts of M1/M2 grades to cyril.furtlehner@inria.fr and chibbaro@lisn.fr. Applications are reviewed until the position is filled.