Learning KPZ dynamics

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Context In the last decade, machine learning, and more specifically deep neural networks, have thoroughly renewed the research perspectives in many fields like Natural Language Processing and Computer Vision. Despite indisputable successes however, the introduction of ML approaches in physical systems remains a challenge to overcome the lack of confidence, acceptability, guarantees and explainability. This project aims at developing new Machine Learning techniques tailored to the modelling and inference of high-dimensional complex physical systems described by partial differential equations (PDEs).

Project For chaotic/stochastic systems, instead of trying to make long-term predictions as accurate as possible on a given dataset of simulations (which does not make sense anyway given the chaotic nature of the dynamical system), we will try to **get at least the statistics correct**. That is, when generating many trajectories, do we produce a rough interface at different spatial scales with the right probabilities? Does our learned system **"look like" the real system in some statistical sense**? We will focus on the paradigmatic model proposed by Kardar-Parisi-Zhang for an interface (KPZ PRL 1986). This is a key point. Spatio-temporal chaos is multi-scale and that is reflected by a lack of self-similarity which leads to an increased probability of having very strong events at the smallest scales. We are interested notably in these rare events. The multiscale character of rough interfaces is visible in Figure 1, where the front evolution of cancer cell colonies is shown, for which KPZ critical exponents were found.

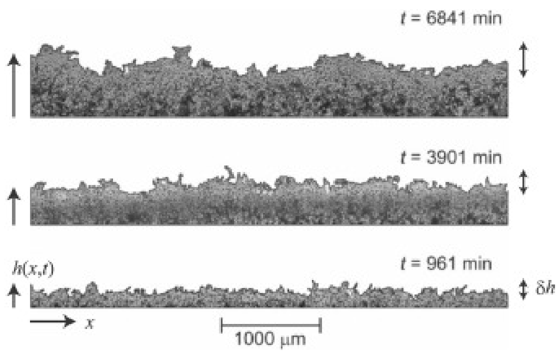

Figure 1: Experimental example of growing interfaces.

Goals (i) To find a suitable neural network architecture; (ii) properly design a training criterion or ML procedure, to train toward predicting the right statistics, notably scaling exponents. We can we can leverage some important properties like symmetries and invariances to address these issues. The project eventually aims at developing novel architectures and structure for the machine learning of complex dynamical systems. This remains a problem yet out of reach, and its success would have an immediate impact.

The project is interdisciplinary. Depending on the skills of the candidate, different tracks can be explored.

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